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Li et al.

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(54) **COMMUNICATIONS METHODS AND APPARATUS FOR ALLOCATION OF RESOURCES AND HANDOVER RELATED MEASUREMENTS**

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(73) Assignee: **QUALCOMM Incorporated**, San Diego, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 15 days.

(21) Appl. No.: **13/828,420**

(22) Filed: **Mar. 14, 2013**

(65) **Prior Publication Data**

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(51) **Int. Cl.**
H04W 72/04 (2009.01)
H04L 5/00 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H04W 72/04*** (2013.01); ***H04L 5/00*** (2013.01); ***H04W 72/0486*** (2013.01); *H04W 48/16* (2013.01); *H04W 52/0206* (2013.01); *H04W 84/045* (2013.01)

(58) **Field of Classification Search**
USPC 455/450, 414.1, 418, 452.1, 67.11, 455/456.5, 436–444; 370/328, 329, 33; 375/316; 715/771
See application file for complete search history.

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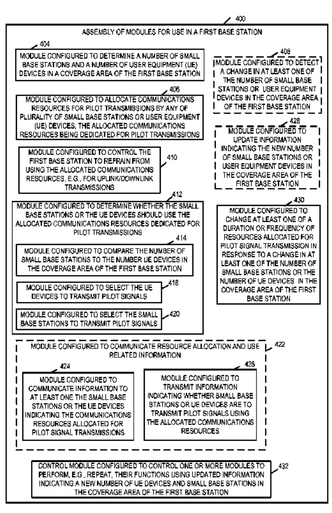
Primary Examiner — Diane Mizrahi
(74) *Attorney, Agent, or Firm* — Holland & Hart LLP

(57) **ABSTRACT**

Methods and apparatus for allocation of resources for handover related measurements in a communications system including user equipment (UE) devices, a macro base station and small base stations (e.g., femtocells) are described. Some embodiments are well suited for systems where the number of femtocells may equal or outnumber the number of UE devices. In some embodiments a macro base station allocates periodic communications resources for transmission of pilots by UEs or femtocells. The macro base station configures either femtocells or active UEs to transmit pilots using the allocated communications resources based on the relative number of femtocells to active UEs in the coverage area of the macro base station, devices which are lower in number transmitting the pilots. Transmitters (UE devices or femtocells) transmit pilots along with identification information using the allocated resource(s) and receivers measure the pilot signals. The pilot signal measurements may be used to make handover decisions.

20 Claims, 14 Drawing Sheets



(51) **Int. Cl.**

H04W 48/16	(2009.01)
H04W 52/02	(2009.01)
H04W 84/04	(2009.01)

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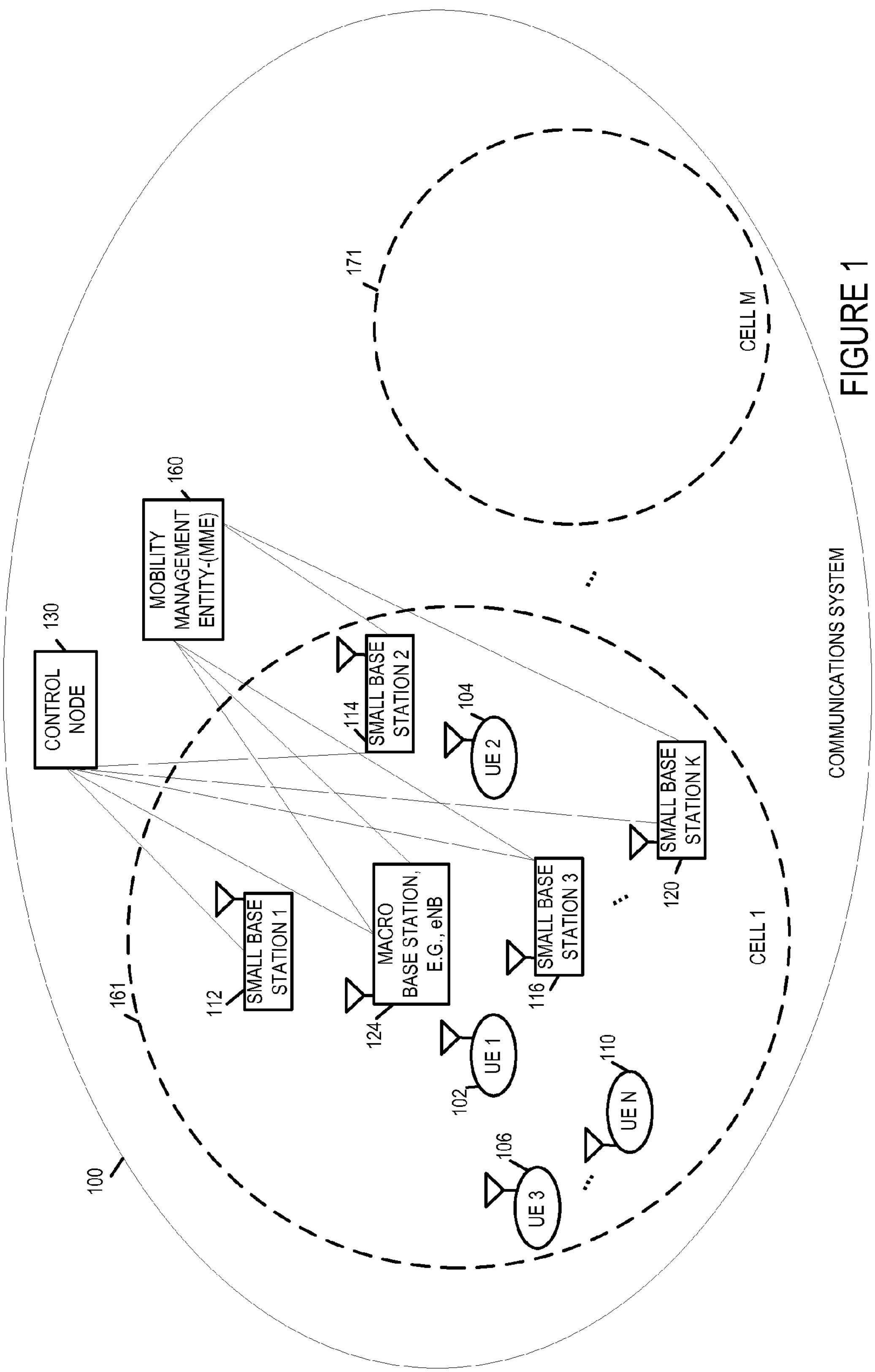
100
161
171
CONTROL NODE
130
MOBILITY MANAGEMENT ENTITY-(MME)
160
SMALL BASE STATION 1
112
MACRO BASE STATION, E.G., eNB
124
SMALL BASE STATION 2
114
SMALL BASE STATION 3
116
SMALL BASE STATION K
120
UE 1
102
UE 2
104
UE 3
106
UE N
110
CELL 1
CELL M
COMMUNICATIONS SYSTEM

FIGURE 1

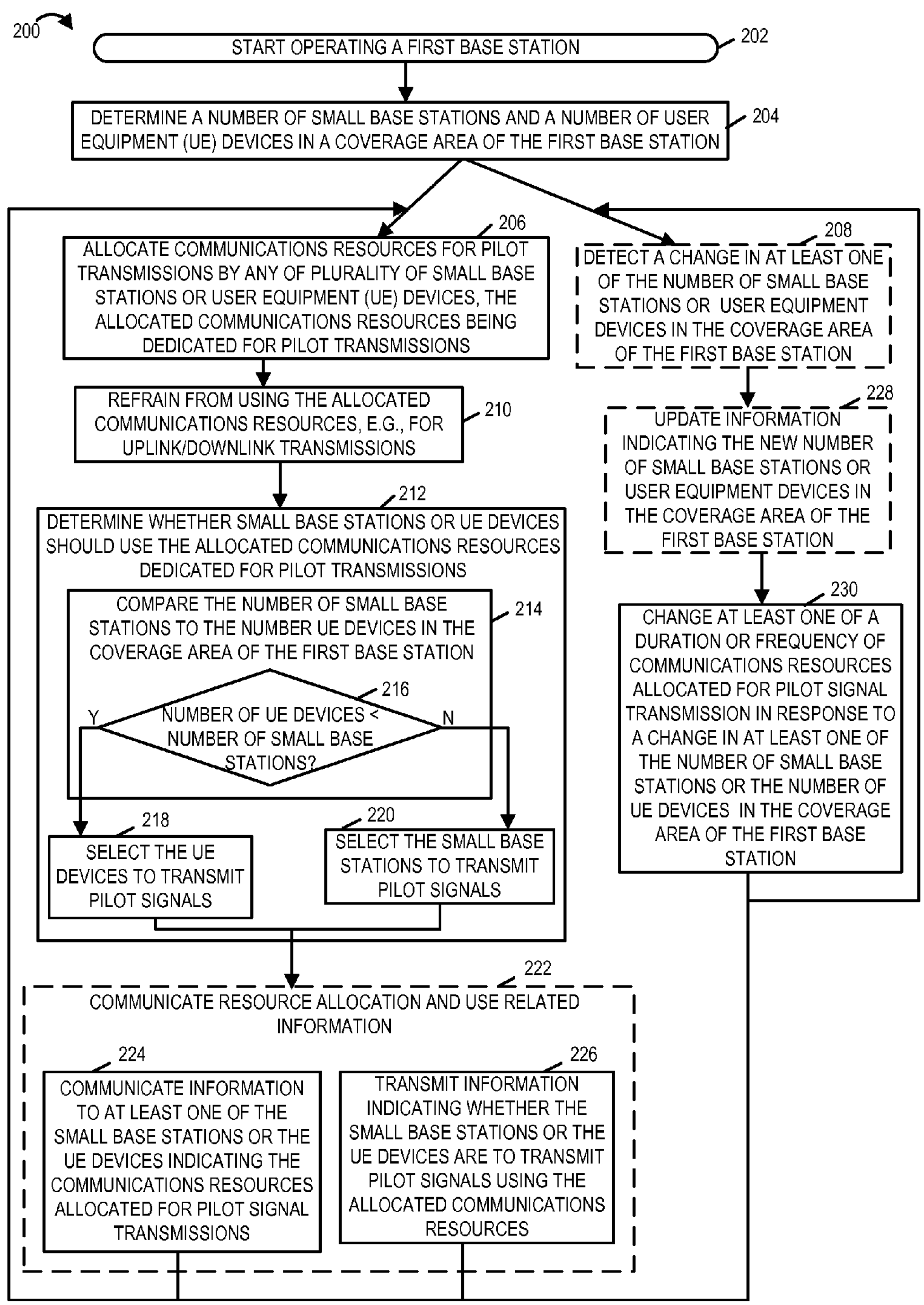
200
START OPERATING A FIRST BASE STATION
202
DETERMINE A NUMBER OF SMALL BASE STATIONS AND A NUMBER OF USER EQUIPMENT (UE) DEVICES IN A COVERAGE AREA OF THE FIRST BASE STATION
204
206
ALLOCATE COMMUNICATIONS RESOURCES FOR PILOT TRANSMISSIONS BY ANY OF PLURALITY OF SMALL BASE STATIONS OR USER EQUIPMENT (UE) DEVICES, THE ALLOCATED COMMUNICATIONS RESOURCES BEING DEDICATED FOR PILOT TRANSMISSIONS
208
DETECT A CHANGE IN AT LEAST ONE OF THE NUMBER OF SMALL BASE STATIONS OR USER EQUIPMENT DEVICES IN THE COVERAGE AREA OF THE FIRST BASE STATION
REFRAIN FROM USING THE ALLOCATED COMMUNICATIONS RESOURCES, E.G., FOR UPLINK/DOWNLINK TRANSMISSIONS
210
228
UPDATE INFORMATION INDICATING THE NEW NUMBER OF SMALL BASE STATIONS OR USER EQUIPMENT DEVICES IN THE COVERAGE AREA OF THE FIRST BASE STATION
212
DETERMINE WHETHER SMALL BASE STATIONS OR UE DEVICES SHOULD USE THE ALLOCATED COMMUNICATIONS RESOURCES DEDICATED FOR PILOT TRANSMISSIONS
COMPARE THE NUMBER OF SMALL BASE STATIONS TO THE NUMBER UE DEVICES IN THE COVERAGE AREA OF THE FIRST BASE STATION
214
216
Y
NUMBER OF UE DEVICES < NUMBER OF SMALL BASE STATIONS?
N
230
CHANGE AT LEAST ONE OF A DURATION OR FREQUENCY OF COMMUNICATIONS RESOURCES ALLOCATED FOR PILOT SIGNAL TRANSMISSION IN RESPONSE TO A CHANGE IN AT LEAST ONE OF THE NUMBER OF SMALL BASE STATIONS OR THE NUMBER OF UE DEVICES IN THE COVERAGE AREA OF THE FIRST BASE STATION
218
SELECT THE UE DEVICES TO TRANSMIT PILOT SIGNALS
220
SELECT THE SMALL BASE STATIONS TO TRANSMIT PILOT SIGNALS
222
COMMUNICATE RESOURCE ALLOCATION AND USE RELATED INFORMATION
224
COMMUNICATE INFORMATION TO AT LEAST ONE OF THE SMALL BASE STATIONS OR THE UE DEVICES INDICATING THE COMMUNICATIONS RESOURCES ALLOCATED FOR PILOT SIGNAL TRANSMISSIONS
226
TRANSMIT INFORMATION INDICATING WHETHER THE SMALL BASE STATIONS OR THE UE DEVICES ARE TO TRANSMIT PILOT SIGNALS USING THE ALLOCATED COMMUNICATIONS RESOURCES

FIGURE 2

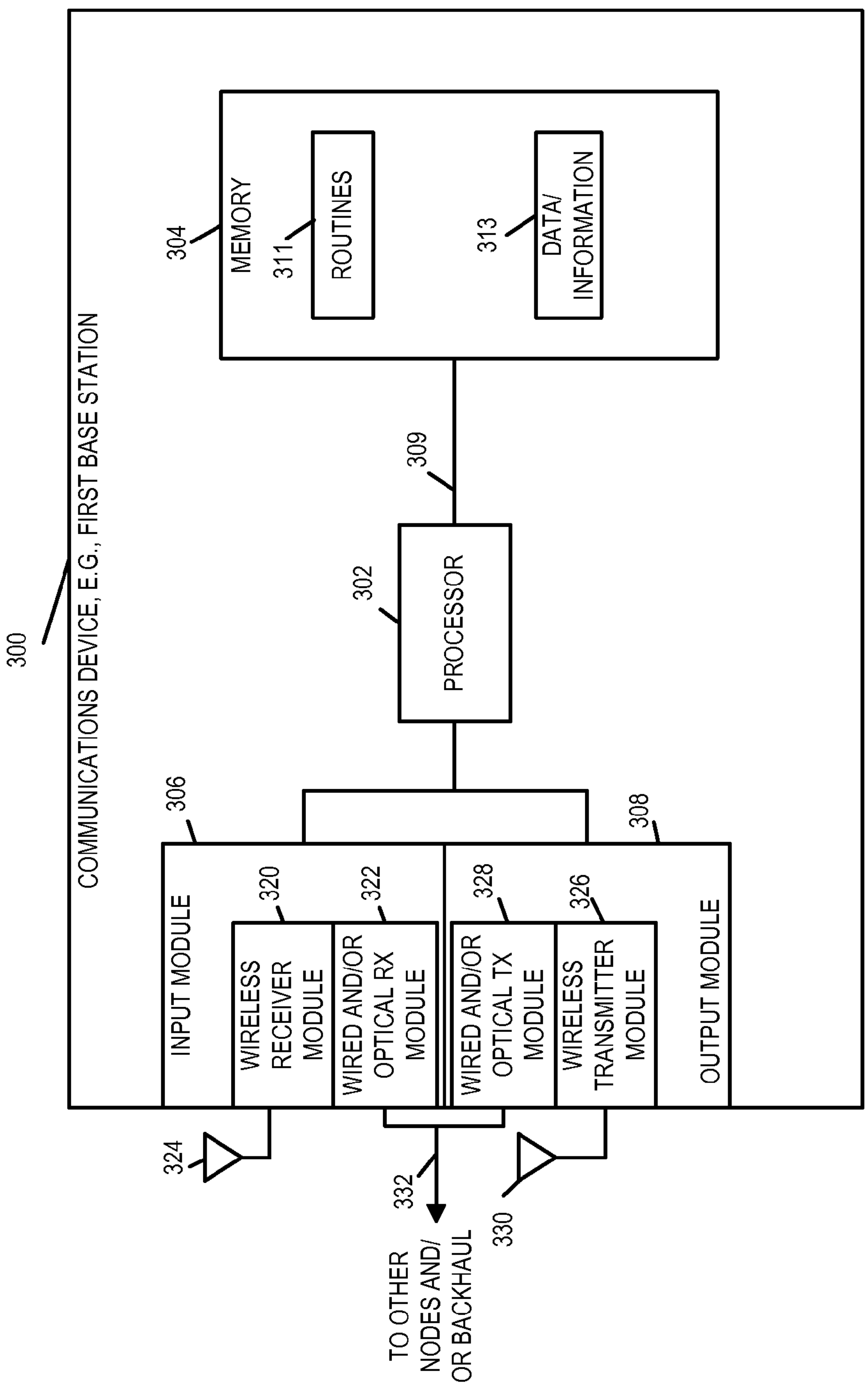
300
COMMUNICATIONS DEVICE, E.G., FIRST BASE STATION
304
MEMORY
311
ROUTINES
313
DATA/
INFORMATION
309
302
PROCESSOR
306
INPUT MODULE
320
WIRELESS
RECEIVER
MODULE
322
WIRED AND/OR
OPTICAL RX
MODULE
328
WIRED AND/OR
OPTICAL TX
MODULE
326
WIRELESS
TRANSMITTER
MODULE
308
OUTPUT MODULE
324
332
330
TO OTHER
NODES AND/
OR BACKHAUL

FIGURE 3

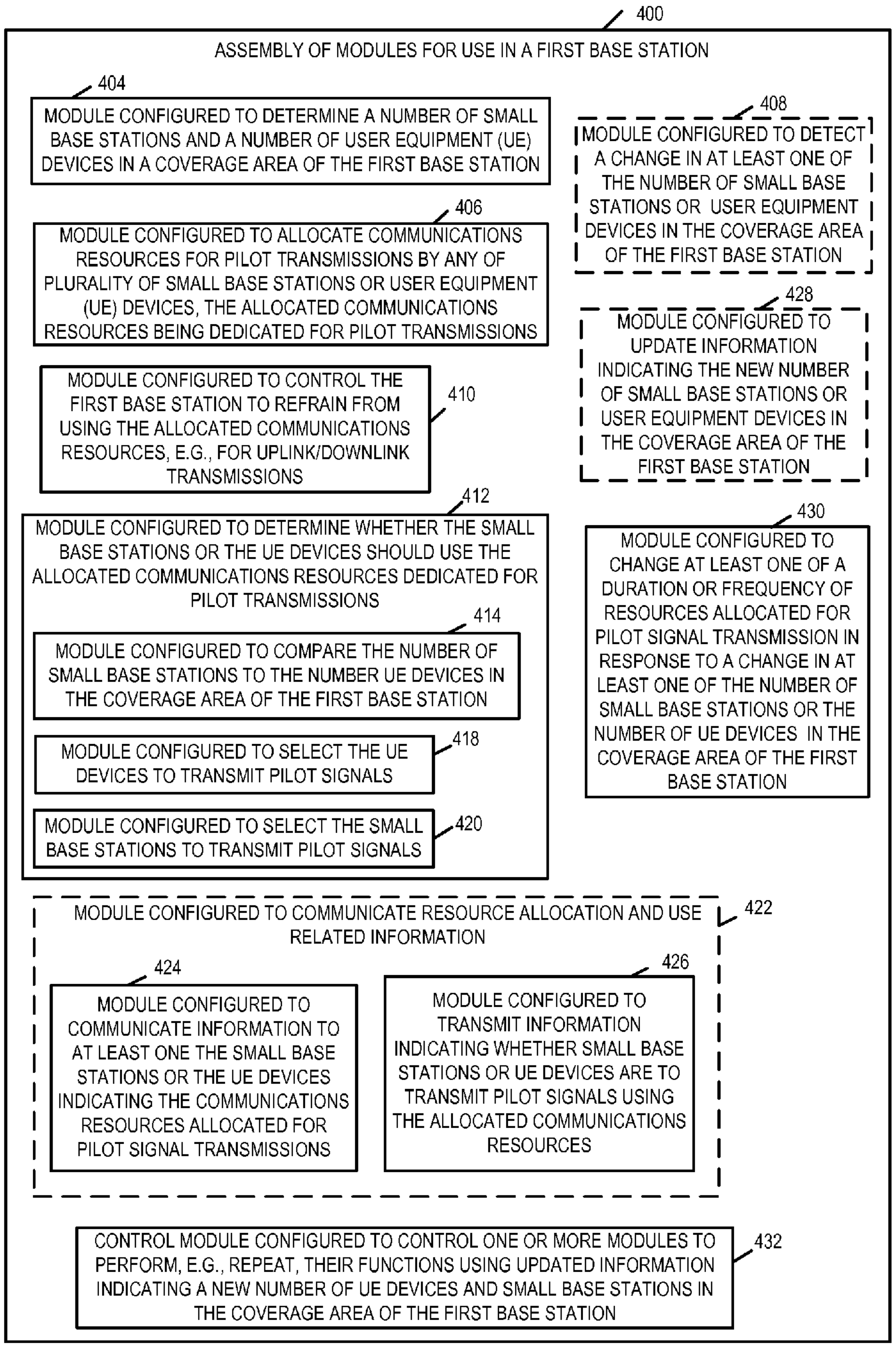
400
ASSEMBLY OF MODULES FOR USE IN A FIRST BASE STATION
404
MODULE CONFIGURED TO DETERMINE A NUMBER OF SMALL BASE STATIONS AND A NUMBER OF USER EQUIPMENT (UE) DEVICES IN A COVERAGE AREA OF THE FIRST BASE STATION
408
MODULE CONFIGURED TO DETECT A CHANGE IN AT LEAST ONE OF THE NUMBER OF SMALL BASE STATIONS OR USER EQUIPMENT DEVICES IN THE COVERAGE AREA OF THE FIRST BASE STATION
406
MODULE CONFIGURED TO ALLOCATE COMMUNICATIONS RESOURCES FOR PILOT TRANSMISSIONS BY ANY OF PLURALITY OF SMALL BASE STATIONS OR USER EQUIPMENT (UE) DEVICES, THE ALLOCATED COMMUNICATIONS RESOURCES BEING DEDICATED FOR PILOT TRANSMISSIONS
428
MODULE CONFIGURED TO UPDATE INFORMATION INDICATING THE NEW NUMBER OF SMALL BASE STATIONS OR USER EQUIPMENT DEVICES IN THE COVERAGE AREA OF THE FIRST BASE STATION
410
MODULE CONFIGURED TO CONTROL THE FIRST BASE STATION TO REFRAIN FROM USING THE ALLOCATED COMMUNICATIONS RESOURCES, E.G., FOR UPLINK/DOWNLINK TRANSMISSIONS
412
MODULE CONFIGURED TO DETERMINE WHETHER THE SMALL BASE STATIONS OR THE UE DEVICES SHOULD USE THE ALLOCATED COMMUNICATIONS RESOURCES DEDICATED FOR PILOT TRANSMISSIONS
414
MODULE CONFIGURED TO COMPARE THE NUMBER OF SMALL BASE STATIONS TO THE NUMBER UE DEVICES IN THE COVERAGE AREA OF THE FIRST BASE STATION
418
MODULE CONFIGURED TO SELECT THE UE DEVICES TO TRANSMIT PILOT SIGNALS
420
MODULE CONFIGURED TO SELECT THE SMALL BASE STATIONS TO TRANSMIT PILOT SIGNALS
430
MODULE CONFIGURED TO CHANGE AT LEAST ONE OF A DURATION OR FREQUENCY OF RESOURCES ALLOCATED FOR PILOT SIGNAL TRANSMISSION IN RESPONSE TO A CHANGE IN AT LEAST ONE OF THE NUMBER OF SMALL BASE STATIONS OR THE NUMBER OF UE DEVICES IN THE COVERAGE AREA OF THE FIRST BASE STATION
422
MODULE CONFIGURED TO COMMUNICATE RESOURCE ALLOCATION AND USE RELATED INFORMATION
424
MODULE CONFIGURED TO COMMUNICATE INFORMATION TO AT LEAST ONE THE SMALL BASE STATIONS OR THE UE DEVICES INDICATING THE COMMUNICATIONS RESOURCES ALLOCATED FOR PILOT SIGNAL TRANSMISSIONS
426
MODULE CONFIGURED TO TRANSMIT INFORMATION INDICATING WHETHER SMALL BASE STATIONS OR UE DEVICES ARE TO TRANSMIT PILOT SIGNALS USING THE ALLOCATED COMMUNICATIONS RESOURCES
432
CONTROL MODULE CONFIGURED TO CONTROL ONE OR MORE MODULES TO PERFORM, E.G., REPEAT, THEIR FUNCTIONS USING UPDATED INFORMATION INDICATING A NEW NUMBER OF UE DEVICES AND SMALL BASE STATIONS IN THE COVERAGE AREA OF THE FIRST BASE STATION

FIGURE 4

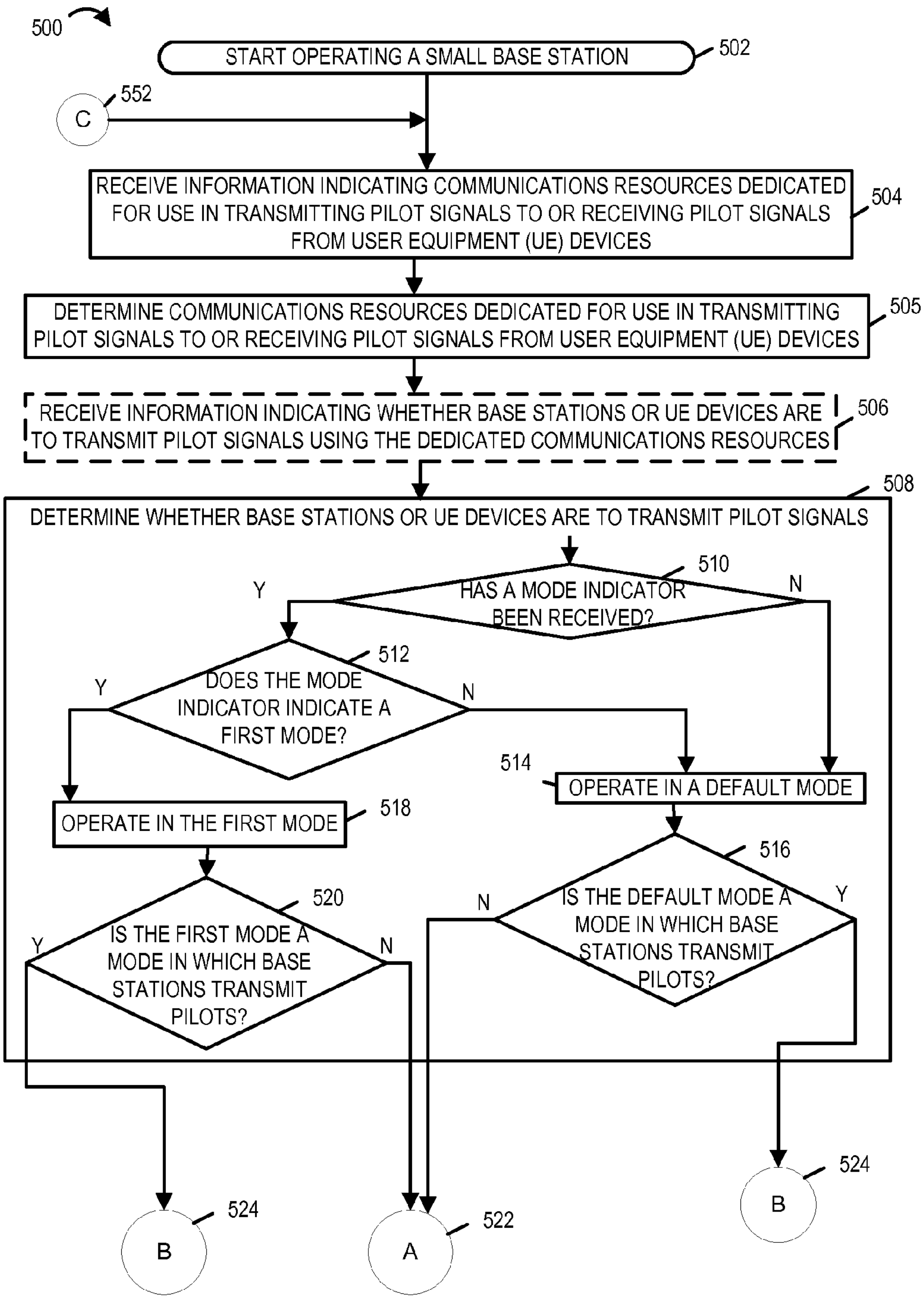

FIGURE 5A

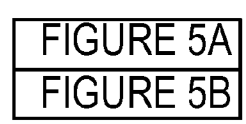

FIGURE 5

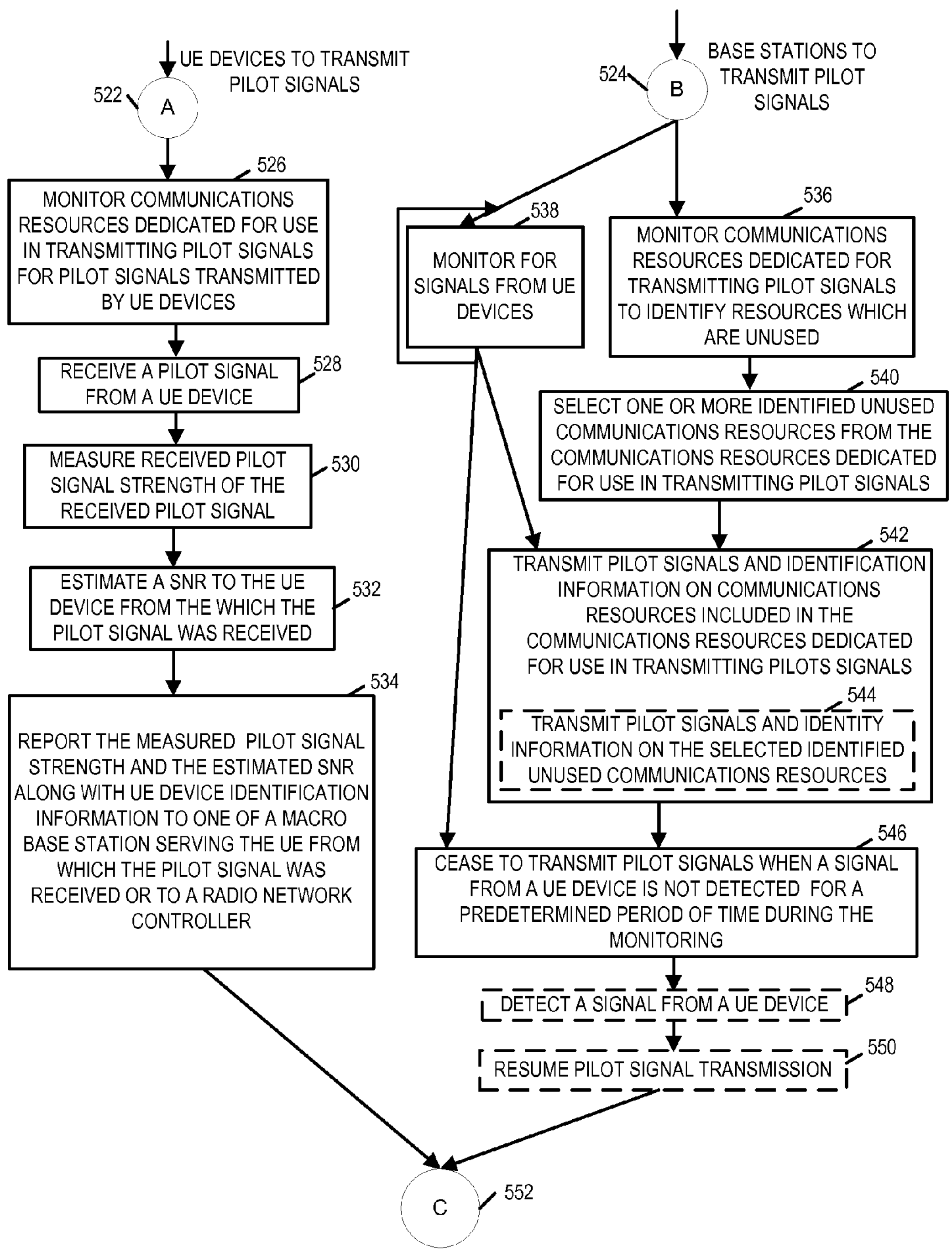
UE DEVICES TO TRANSMIT PILOT SIGNALS
522
A
526
MONITOR COMMUNICATIONS RESOURCES DEDICATED FOR USE IN TRANSMITTING PILOT SIGNALS FOR PILOT SIGNALS TRANSMITTED BY UE DEVICES
528
RECEIVE A PILOT SIGNAL FROM A UE DEVICE
530
MEASURE RECEIVED PILOT SIGNAL STRENGTH OF THE RECEIVED PILOT SIGNAL
532
ESTIMATE A SNR TO THE UE DEVICE FROM THE WHICH THE PILOT SIGNAL WAS RECEIVED
534
REPORT THE MEASURED PILOT SIGNAL STRENGTH AND THE ESTIMATED SNR ALONG WITH UE DEVICE IDENTIFICATION INFORMATION TO ONE OF A MACRO BASE STATION SERVING THE UE FROM WHICH THE PILOT SIGNAL WAS RECEIVED OR TO A RADIO NETWORK CONTROLLER
BASE STATIONS TO TRANSMIT PILOT SIGNALS
524
B
538
MONITOR FOR SIGNALS FROM UE DEVICES
536
MONITOR COMMUNICATIONS RESOURCES DEDICATED FOR TRANSMITTING PILOT SIGNALS TO IDENTIFY RESOURCES WHICH ARE UNUSED
540
SELECT ONE OR MORE IDENTIFIED UNUSED COMMUNICATIONS RESOURCES FROM THE COMMUNICATIONS RESOURCES DEDICATED FOR USE IN TRANSMITTING PILOT SIGNALS
542
TRANSMIT PILOT SIGNALS AND IDENTIFICATION INFORMATION ON COMMUNICATIONS RESOURCES INCLUDED IN THE COMMUNICATIONS RESOURCES DEDICATED FOR USE IN TRANSMITTING PILOTS SIGNALS
544
TRANSMIT PILOT SIGNALS AND IDENTITY INFORMATION ON THE SELECTED IDENTIFIED UNUSED COMMUNICATIONS RESOURCES
546
CEASE TO TRANSMIT PILOT SIGNALS WHEN A SIGNAL FROM A UE DEVICE IS NOT DETECTED FOR A PREDETERMINED PERIOD OF TIME DURING THE MONITORING
548
DETECT A SIGNAL FROM A UE DEVICE
550
RESUME PILOT SIGNAL TRANSMISSION
C
552

FIGURE 5B

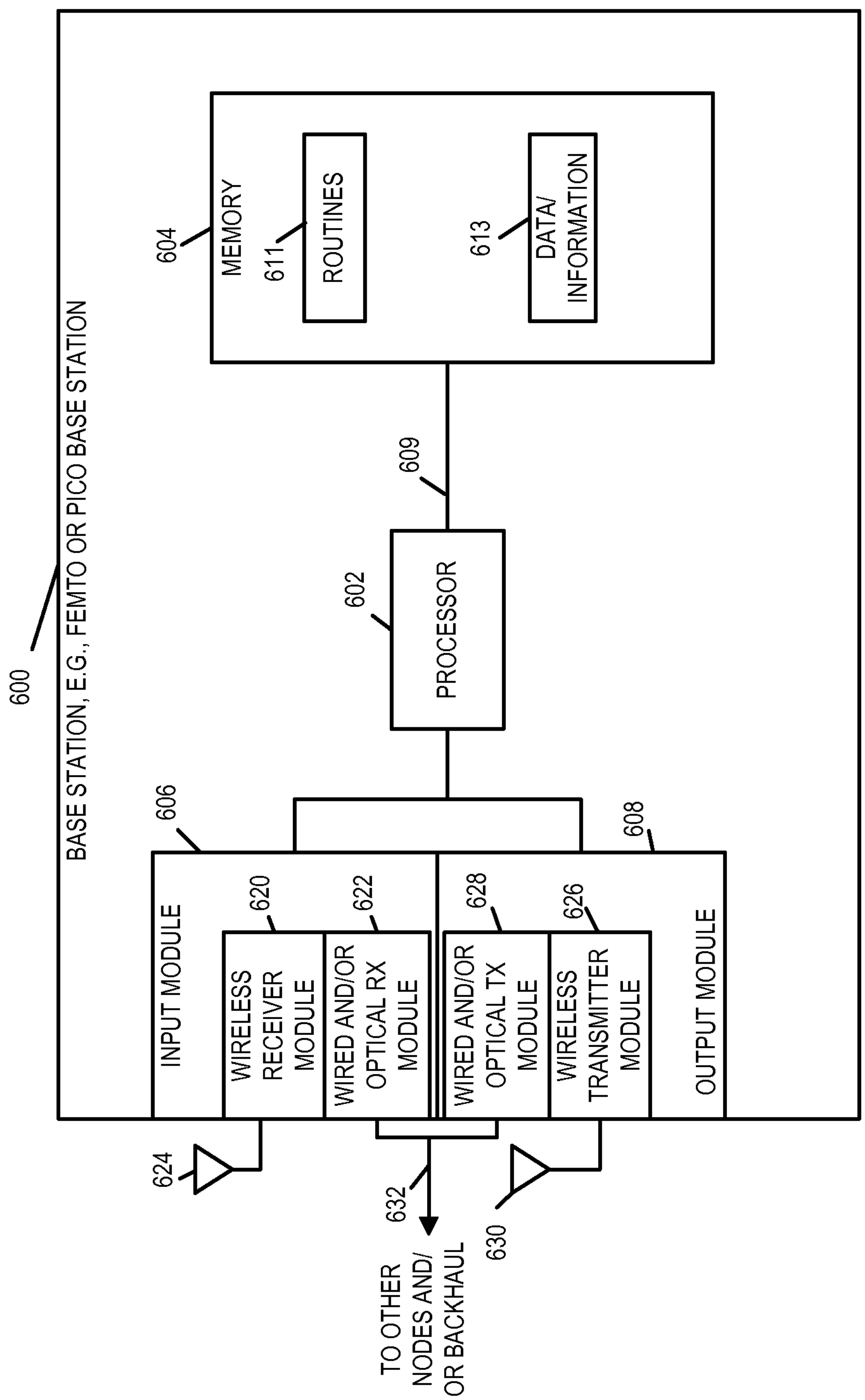
600
BASE STATION, E.G., FEMTO OR PICO BASE STATION
604
MEMORY
611
ROUTINES
613
DATA/
INFORMATION
609
602
PROCESSOR
606
INPUT MODULE
620
WIRELESS
RECEIVER
MODULE
622
WIRED AND/OR
OPTICAL RX
MODULE
608
628
WIRED AND/OR
OPTICAL TX
MODULE
626
WIRELESS
TRANSMITTER
MODULE
OUTPUT MODULE
624
632
630
TO OTHER
NODES AND/
OR BACKHAUL

FIGURE 6

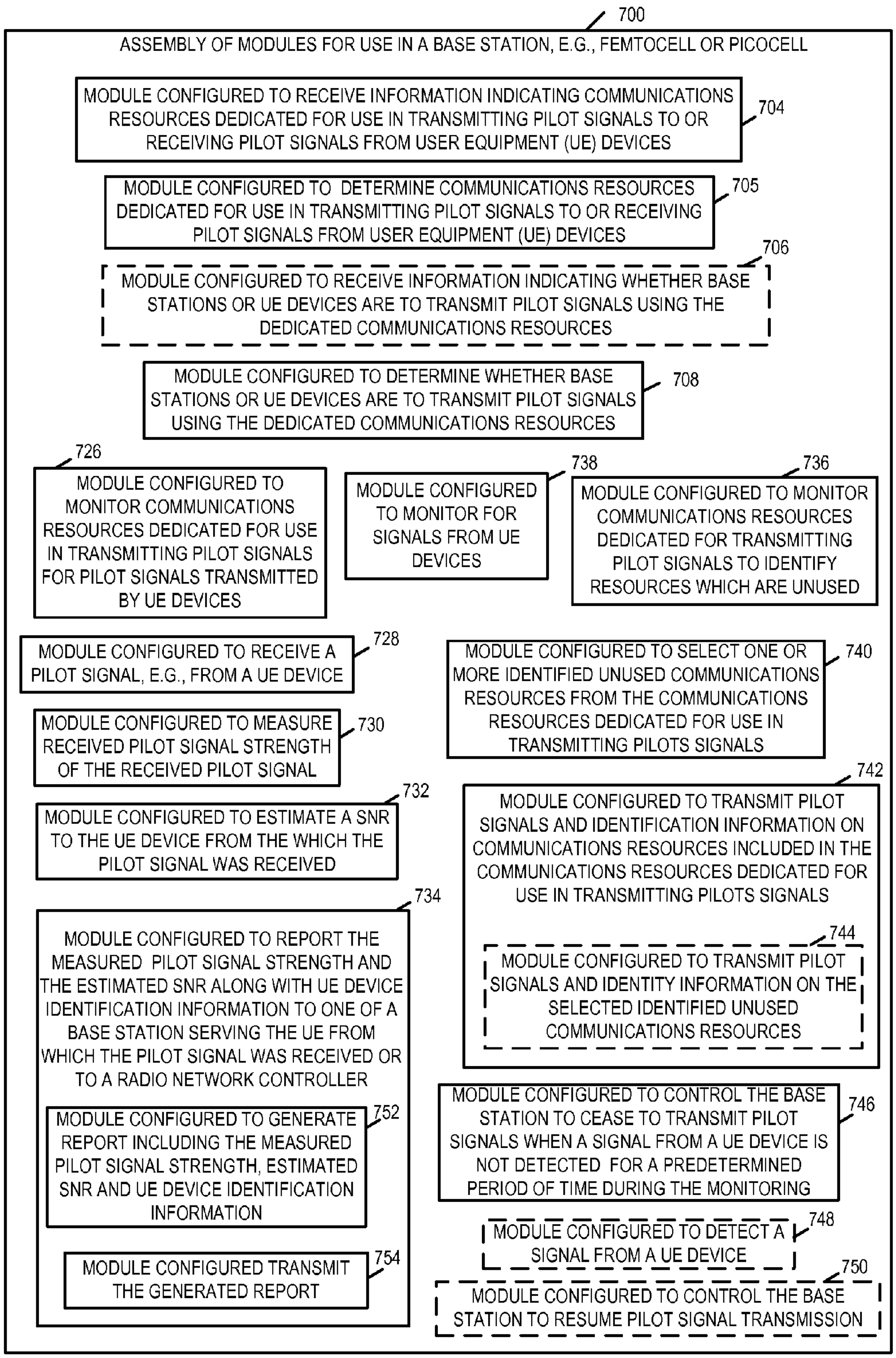
700
ASSEMBLY OF MODULES FOR USE IN A BASE STATION, E.G., FEMTOCELL OR PICOCELL
MODULE CONFIGURED TO RECEIVE INFORMATION INDICATING COMMUNICATIONS RESOURCES DEDICATED FOR USE IN TRANSMITTING PILOT SIGNALS TO OR RECEIVING PILOT SIGNALS FROM USER EQUIPMENT (UE) DEVICES
704
MODULE CONFIGURED TO DETERMINE COMMUNICATIONS RESOURCES DEDICATED FOR USE IN TRANSMITTING PILOT SIGNALS TO OR RECEIVING PILOT SIGNALS FROM USER EQUIPMENT (UE) DEVICES
705
706
MODULE CONFIGURED TO RECEIVE INFORMATION INDICATING WHETHER BASE STATIONS OR UE DEVICES ARE TO TRANSMIT PILOT SIGNALS USING THE DEDICATED COMMUNICATIONS RESOURCES
MODULE CONFIGURED TO DETERMINE WHETHER BASE STATIONS OR UE DEVICES ARE TO TRANSMIT PILOT SIGNALS USING THE DEDICATED COMMUNICATIONS RESOURCES
708
726
MODULE CONFIGURED TO MONITOR COMMUNICATIONS RESOURCES DEDICATED FOR USE IN TRANSMITTING PILOT SIGNALS FOR PILOT SIGNALS TRANSMITTED BY UE DEVICES
MODULE CONFIGURED TO MONITOR FOR SIGNALS FROM UE DEVICES
738
736
MODULE CONFIGURED TO MONITOR COMMUNICATIONS RESOURCES DEDICATED FOR TRANSMITTING PILOT SIGNALS TO IDENTIFY RESOURCES WHICH ARE UNUSED
MODULE CONFIGURED TO RECEIVE A PILOT SIGNAL, E.G., FROM A UE DEVICE
728
MODULE CONFIGURED TO SELECT ONE OR MORE IDENTIFIED UNUSED COMMUNICATIONS RESOURCES FROM THE COMMUNICATIONS RESOURCES DEDICATED FOR USE IN TRANSMITTING PILOTS SIGNALS
740
MODULE CONFIGURED TO MEASURE RECEIVED PILOT SIGNAL STRENGTH OF THE RECEIVED PILOT SIGNAL
730
732
MODULE CONFIGURED TO ESTIMATE A SNR TO THE UE DEVICE FROM THE WHICH THE PILOT SIGNAL WAS RECEIVED
742
MODULE CONFIGURED TO TRANSMIT PILOT SIGNALS AND IDENTIFICATION INFORMATION ON COMMUNICATIONS RESOURCES INCLUDED IN THE COMMUNICATIONS RESOURCES DEDICATED FOR USE IN TRANSMITTING PILOTS SIGNALS
744
MODULE CONFIGURED TO TRANSMIT PILOT SIGNALS AND IDENTITY INFORMATION ON THE SELECTED IDENTIFIED UNUSED COMMUNICATIONS RESOURCES
734
MODULE CONFIGURED TO REPORT THE MEASURED PILOT SIGNAL STRENGTH AND THE ESTIMATED SNR ALONG WITH UE DEVICE IDENTIFICATION INFORMATION TO ONE OF A BASE STATION SERVING THE UE FROM WHICH THE PILOT SIGNAL WAS RECEIVED OR TO A RADIO NETWORK CONTROLLER
MODULE CONFIGURED TO GENERATE REPORT INCLUDING THE MEASURED PILOT SIGNAL STRENGTH, ESTIMATED SNR AND UE DEVICE IDENTIFICATION INFORMATION
752
MODULE CONFIGURED TO CONTROL THE BASE STATION TO CEASE TO TRANSMIT PILOT SIGNALS WHEN A SIGNAL FROM A UE DEVICE IS NOT DETECTED FOR A PREDETERMINED PERIOD OF TIME DURING THE MONITORING
746
MODULE CONFIGURED TO DETECT A SIGNAL FROM A UE DEVICE
748
MODULE CONFIGURED TRANSMIT THE GENERATED REPORT
754
750
MODULE CONFIGURED TO CONTROL THE BASE STATION TO RESUME PILOT SIGNAL TRANSMISSION

FIGURE 7

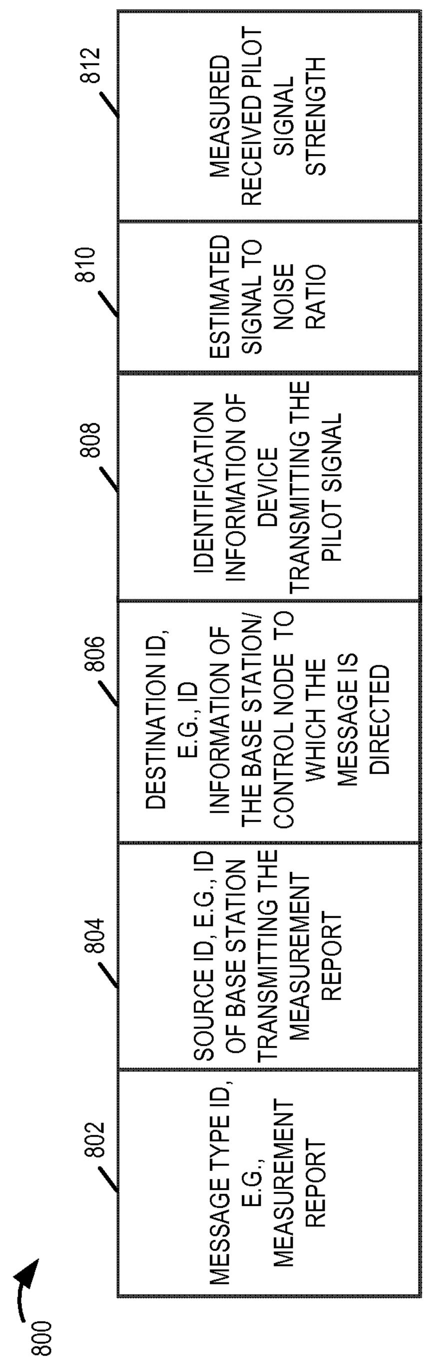
800
802
MESSAGE TYPE ID, E.G., MEASUREMENT REPORT
804
SOURCE ID, E.G., ID OF BASE STATION TRANSMITTING THE MEASUREMENT REPORT
806
DESTINATION ID, E.G., ID INFORMATION OF THE BASE STATION/ CONTROL NODE TO WHICH THE MESSAGE IS DIRECTED
808
IDENTIFICATION INFORMATION OF DEVICE TRANSMITTING THE PILOT SIGNAL
810
ESTIMATED SIGNAL TO NOISE RATIO
812
MEASURED RECEIVED PILOT SIGNAL STRENGTH

FIGURE 8

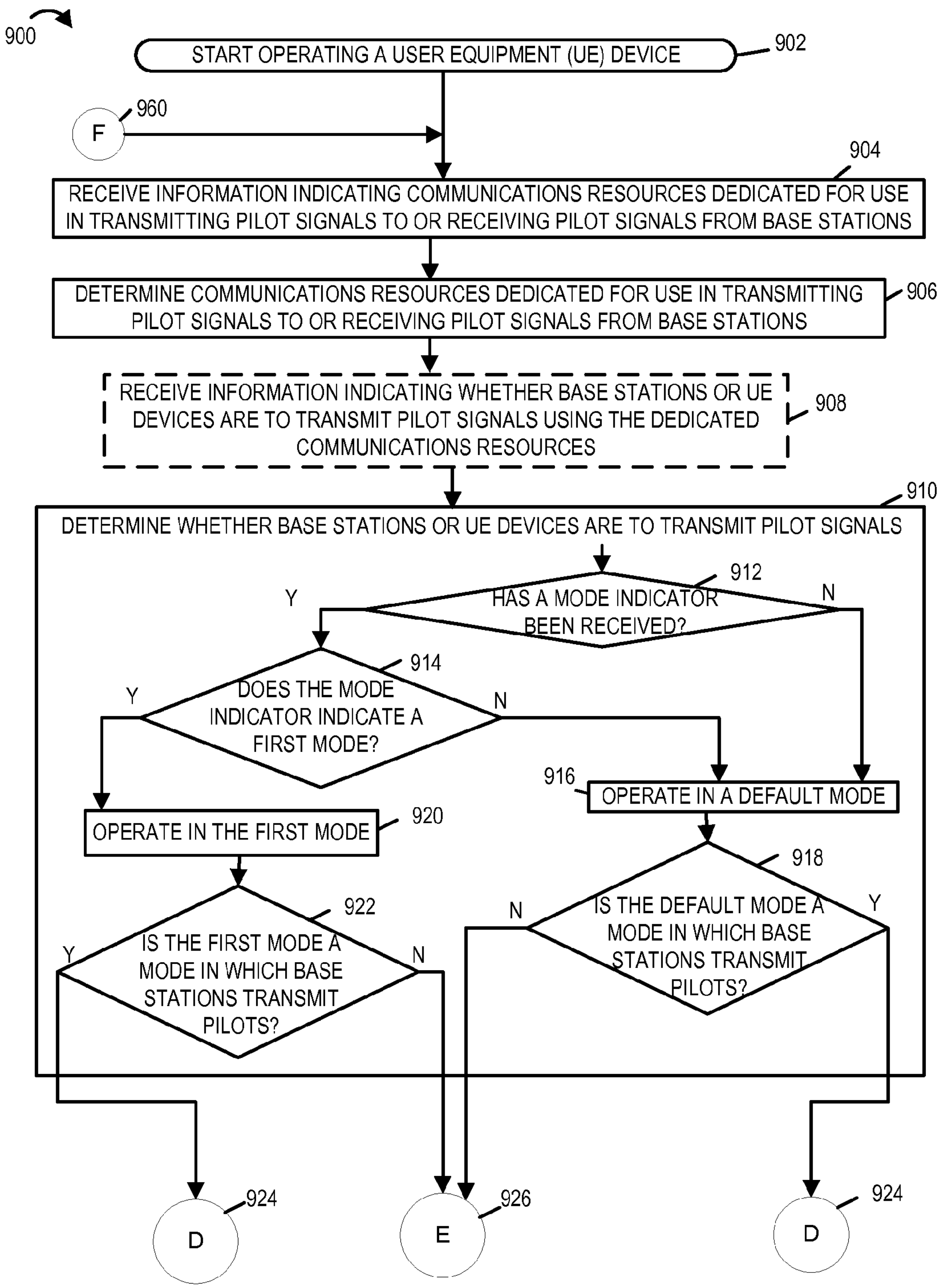

FIGURE 9A

FIGURE 9A
FIGURE 9B

FIGURE 9

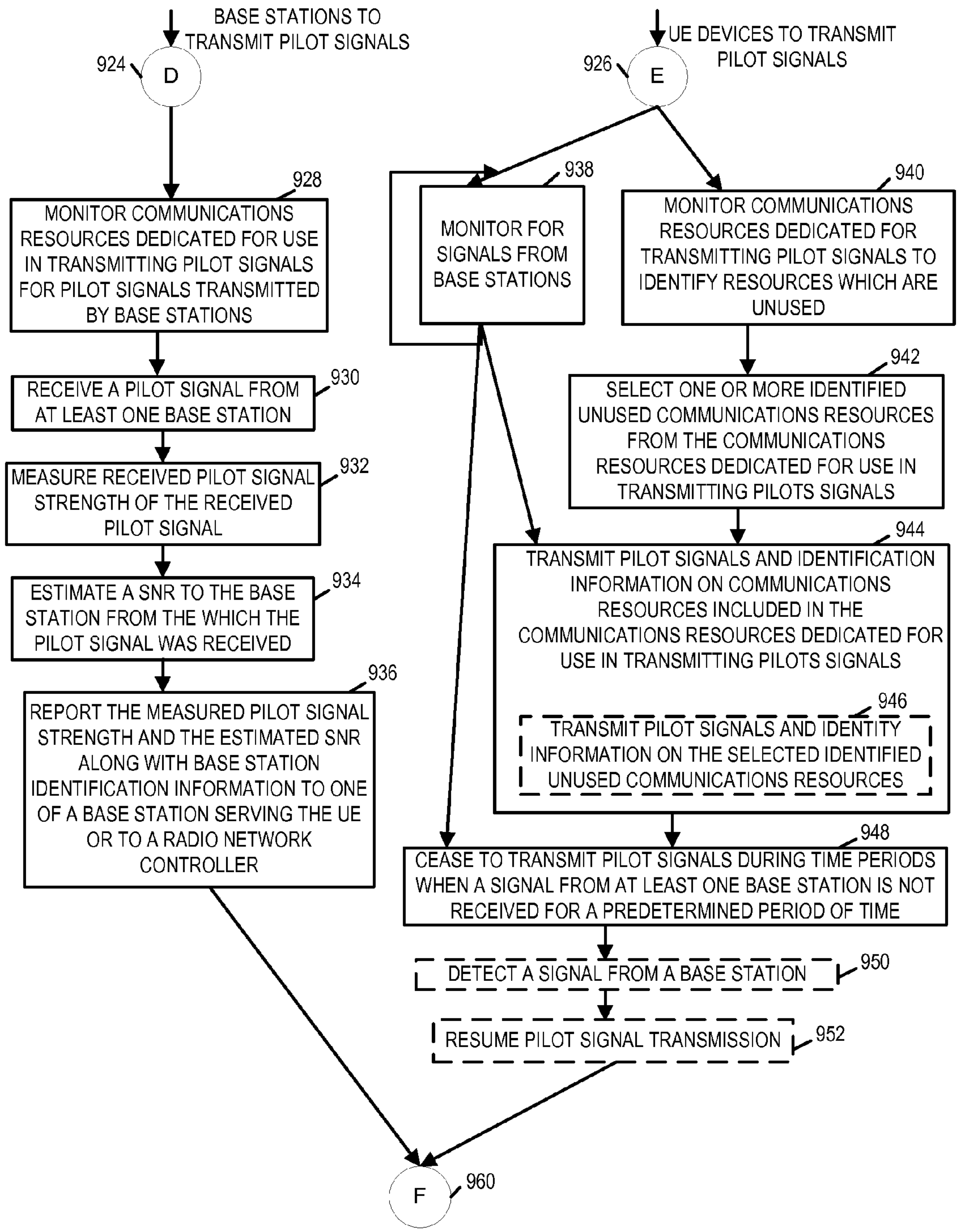
BASE STATIONS TO TRANSMIT PILOT SIGNALS
924
D
UE DEVICES TO TRANSMIT PILOT SIGNALS
926
E
928
MONITOR COMMUNICATIONS RESOURCES DEDICATED FOR USE IN TRANSMITTING PILOT SIGNALS FOR PILOT SIGNALS TRANSMITTED BY BASE STATIONS
930
RECEIVE A PILOT SIGNAL FROM AT LEAST ONE BASE STATION
932
MEASURE RECEIVED PILOT SIGNAL STRENGTH OF THE RECEIVED PILOT SIGNAL
934
ESTIMATE A SNR TO THE BASE STATION FROM THE WHICH THE PILOT SIGNAL WAS RECEIVED
936
REPORT THE MEASURED PILOT SIGNAL STRENGTH AND THE ESTIMATED SNR ALONG WITH BASE STATION IDENTIFICATION INFORMATION TO ONE OF A BASE STATION SERVING THE UE OR TO A RADIO NETWORK CONTROLLER
938
MONITOR FOR SIGNALS FROM BASE STATIONS
940
MONITOR COMMUNICATIONS RESOURCES DEDICATED FOR TRANSMITTING PILOT SIGNALS TO IDENTIFY RESOURCES WHICH ARE UNUSED
942
SELECT ONE OR MORE IDENTIFIED UNUSED COMMUNICATIONS RESOURCES FROM THE COMMUNICATIONS RESOURCES DEDICATED FOR USE IN TRANSMITTING PILOTS SIGNALS
944
TRANSMIT PILOT SIGNALS AND IDENTIFICATION INFORMATION ON COMMUNICATIONS RESOURCES INCLUDED IN THE COMMUNICATIONS RESOURCES DEDICATED FOR USE IN TRANSMITTING PILOTS SIGNALS
946
TRANSMIT PILOT SIGNALS AND IDENTITY INFORMATION ON THE SELECTED IDENTIFIED UNUSED COMMUNICATIONS RESOURCES
948
CEASE TO TRANSMIT PILOT SIGNALS DURING TIME PERIODS WHEN A SIGNAL FROM AT LEAST ONE BASE STATION IS NOT RECEIVED FOR A PREDETERMINED PERIOD OF TIME
950
DETECT A SIGNAL FROM A BASE STATION
952
RESUME PILOT SIGNAL TRANSMISSION
960
F

FIGURE 9B

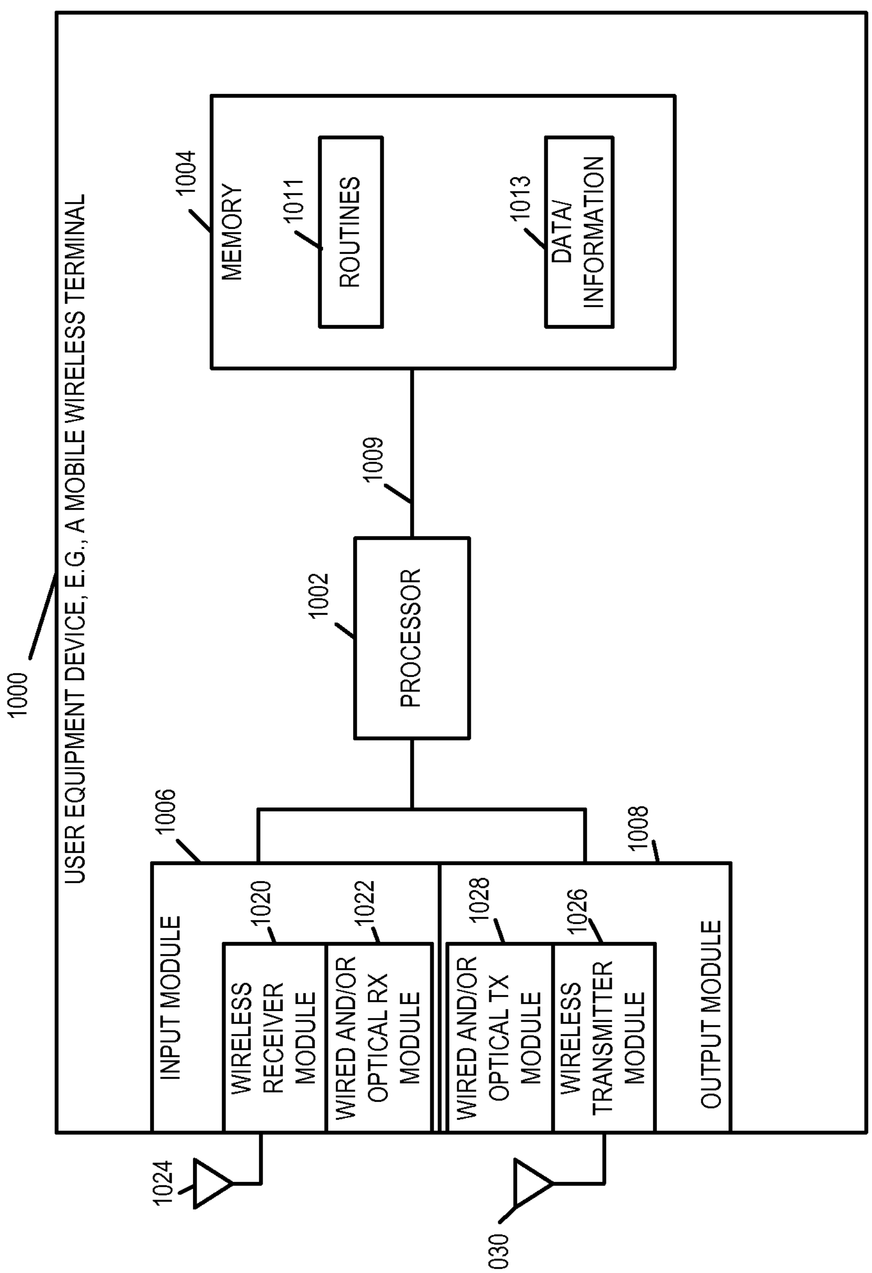
1000
USER EQUIPMENT DEVICE, E.G., A MOBILE WIRELESS TERMINAL
1004
MEMORY
1011
ROUTINES
1013
DATA/
INFORMATION
1009
1002
PROCESSOR
1006
1008
INPUT MODULE
1020
WIRELESS
RECEIVER
MODULE
1022
WIRED AND/OR
OPTICAL RX
MODULE
1028
WIRED AND/OR
OPTICAL TX
MODULE
1026
WIRELESS
TRANSMITTER
MODULE
OUTPUT MODULE
1024
1030

FIGURE 10

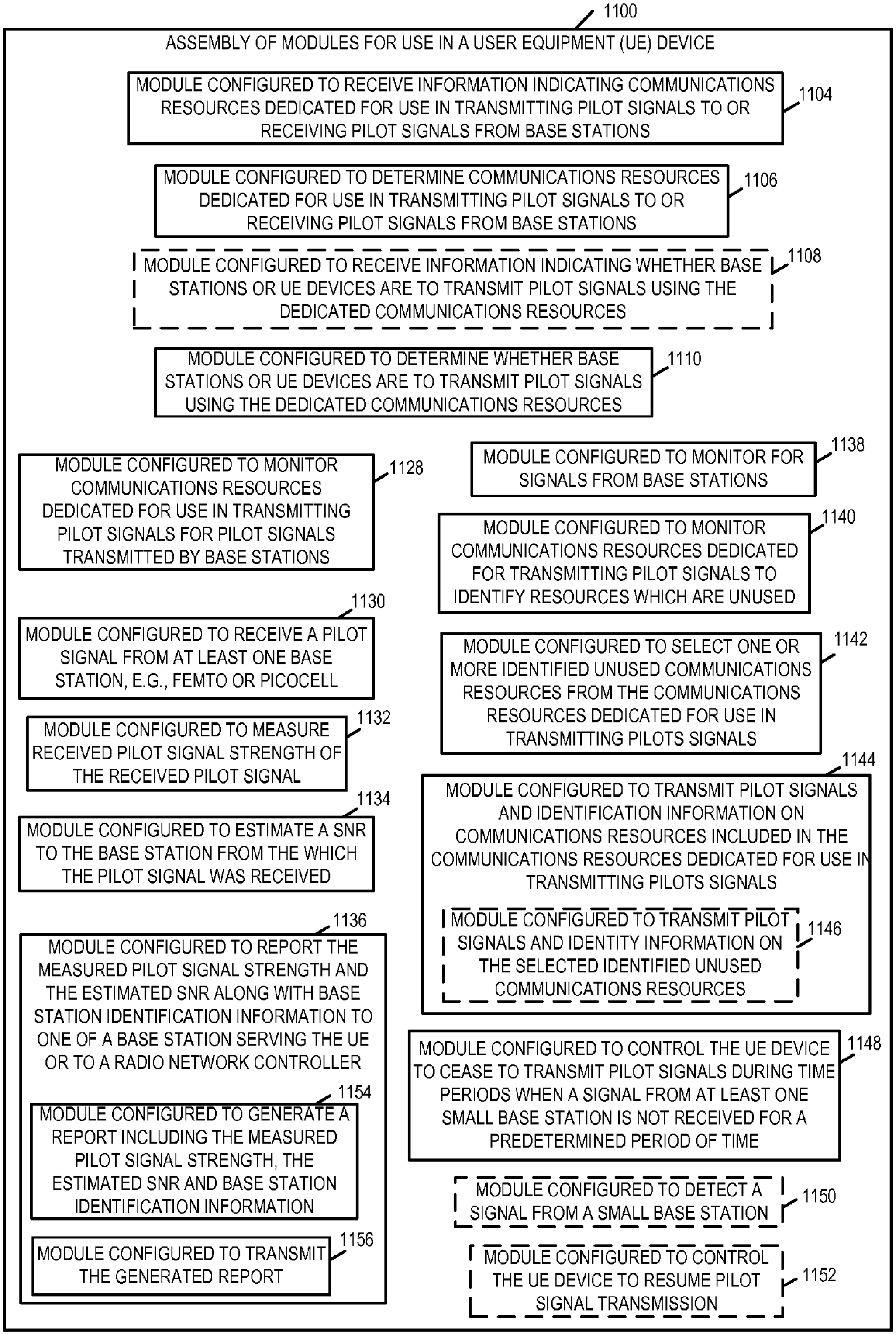
1100
ASSEMBLY OF MODULES FOR USE IN A USER EQUIPMENT (UE) DEVICE
MODULE CONFIGURED TO RECEIVE INFORMATION INDICATING COMMUNICATIONS RESOURCES DEDICATED FOR USE IN TRANSMITTING PILOT SIGNALS TO OR RECEIVING PILOT SIGNALS FROM BASE STATIONS
1104
MODULE CONFIGURED TO DETERMINE COMMUNICATIONS RESOURCES DEDICATED FOR USE IN TRANSMITTING PILOT SIGNALS TO OR RECEIVING PILOT SIGNALS FROM BASE STATIONS
1106
MODULE CONFIGURED TO RECEIVE INFORMATION INDICATING WHETHER BASE STATIONS OR UE DEVICES ARE TO TRANSMIT PILOT SIGNALS USING THE DEDICATED COMMUNICATIONS RESOURCES
1108
MODULE CONFIGURED TO DETERMINE WHETHER BASE STATIONS OR UE DEVICES ARE TO TRANSMIT PILOT SIGNALS USING THE DEDICATED COMMUNICATIONS RESOURCES
1110
MODULE CONFIGURED TO MONITOR COMMUNICATIONS RESOURCES DEDICATED FOR USE IN TRANSMITTING PILOT SIGNALS FOR PILOT SIGNALS TRANSMITTED BY BASE STATIONS
1128
MODULE CONFIGURED TO RECEIVE A PILOT SIGNAL FROM AT LEAST ONE BASE STATION, E.G., FEMTO OR PICOCELL
1130
MODULE CONFIGURED TO MEASURE RECEIVED PILOT SIGNAL STRENGTH OF THE RECEIVED PILOT SIGNAL
1132
MODULE CONFIGURED TO ESTIMATE A SNR TO THE BASE STATION FROM THE WHICH THE PILOT SIGNAL WAS RECEIVED
1134
MODULE CONFIGURED TO REPORT THE MEASURED PILOT SIGNAL STRENGTH AND THE ESTIMATED SNR ALONG WITH BASE STATION IDENTIFICATION INFORMATION TO ONE OF A BASE STATION SERVING THE UE OR TO A RADIO NETWORK CONTROLLER
1136
MODULE CONFIGURED TO GENERATE A REPORT INCLUDING THE MEASURED PILOT SIGNAL STRENGTH, THE ESTIMATED SNR AND BASE STATION IDENTIFICATION INFORMATION
1154
MODULE CONFIGURED TO TRANSMIT THE GENERATED REPORT
1156
MODULE CONFIGURED TO MONITOR FOR SIGNALS FROM BASE STATIONS
1138
MODULE CONFIGURED TO MONITOR COMMUNICATIONS RESOURCES DEDICATED FOR TRANSMITTING PILOT SIGNALS TO IDENTIFY RESOURCES WHICH ARE UNUSED
1140
MODULE CONFIGURED TO SELECT ONE OR MORE IDENTIFIED UNUSED COMMUNICATIONS RESOURCES FROM THE COMMUNICATIONS RESOURCES DEDICATED FOR USE IN TRANSMITTING PILOTS SIGNALS
1142
MODULE CONFIGURED TO TRANSMIT PILOT SIGNALS AND IDENTIFICATION INFORMATION ON COMMUNICATIONS RESOURCES INCLUDED IN THE COMMUNICATIONS RESOURCES DEDICATED FOR USE IN TRANSMITTING PILOTS SIGNALS
1144
MODULE CONFIGURED TO TRANSMIT PILOT SIGNALS AND IDENTITY INFORMATION ON THE SELECTED IDENTIFIED UNUSED COMMUNICATIONS RESOURCES
1146
MODULE CONFIGURED TO CONTROL THE UE DEVICE TO CEASE TO TRANSMIT PILOT SIGNALS DURING TIME PERIODS WHEN A SIGNAL FROM AT LEAST ONE SMALL BASE STATION IS NOT RECEIVED FOR A PREDETERMINED PERIOD OF TIME
1148
MODULE CONFIGURED TO DETECT A SIGNAL FROM A SMALL BASE STATION
1150
MODULE CONFIGURED TO CONTROL THE UE DEVICE TO RESUME PILOT SIGNAL TRANSMISSION
1152

FIGURE 11

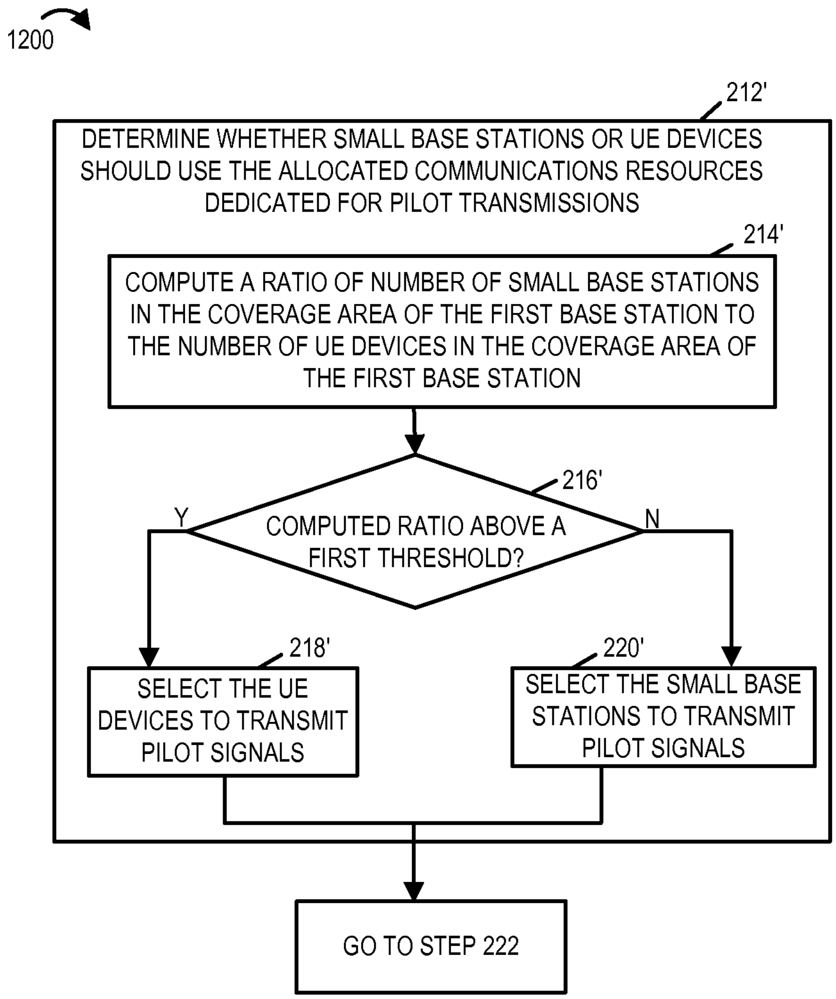
1200
212'
DETERMINE WHETHER SMALL BASE STATIONS OR UE DEVICES SHOULD USE THE ALLOCATED COMMUNICATIONS RESOURCES DEDICATED FOR PILOT TRANSMISSIONS
214'
COMPUTE A RATIO OF NUMBER OF SMALL BASE STATIONS IN THE COVERAGE AREA OF THE FIRST BASE STATION TO THE NUMBER OF UE DEVICES IN THE COVERAGE AREA OF THE FIRST BASE STATION
216'
COMPUTED RATIO ABOVE A FIRST THRESHOLD?
Y
N
218'
SELECT THE UE DEVICES TO TRANSMIT PILOT SIGNALS
220'
SELECT THE SMALL BASE STATIONS TO TRANSMIT PILOT SIGNALS
GO TO STEP 222

FIGURE 12

COMMUNICATIONS METHODS AND APPARATUS FOR ALLOCATION OF RESOURCES AND HANDOVER RELATED MEASUREMENTS

FIELD

Various embodiments relate to wireless communications methods and apparatus and, more particularly, to wireless communications methods and apparatus for efficient allocation of communications resources for signal, e.g., pilot signal, transmissions and related measurements in systems where small, e.g., femto and/or pico, base stations are deployed in addition to mobile wireless terminals and macro base stations.

BACKGROUND

In cellular systems normally the base-stations transmit wideband pilots, e.g., in every sub-frame, for channel estimations as well as for RSSI (Received Signal Strength Indication) measurements. The handover related measurements are traditionally done by the User Equipment (UE) devices, e.g., wireless terminals such as cell phones. In normal cellular systems, UEs perform measurements on the received pilot signals and report the RSSI measurements of a candidate base station for handover to the serving base station. The working assumptions of such designs are that the base stations are deployed in a planned fashion, the base stations are always transmitting, and that the number of UEs is much larger than the number of base stations. However with the deployment of small base stations (also referred to as small cells) in various systems such assumptions are not always valid.

It is envisioned that the future cellular systems will have a dense and unplanned deployment of the small cells. With dense and unplanned deployment of small base stations with small coverage areas, it is not efficient that the small cells transmit pilots in each sub-frame as it causes pilot pollution (e.g., interference between pilot signals). Pilots of the small cells interfere with each other and are interfered by traffic from active small cells and macro cells. This may result in erroneous RSSI measurements made by UEs.

When the number of UEs in a region is comparable to or less than the number of small cells, many small cells are often not in communications with a UE, i.e., many small cells will not have a UE attached to them most of the time. The pilot transmissions by such small cells can cause interference to active small cells' transmissions, e.g., the transmissions by small base stations which have active UEs attached to them. Furthermore, the pilot transmissions also increase power consumption of the small cells as compared to the amount of power which would be required if such transmission did not have to be made.

While under some conditions, the number of small cells in an area may outnumber the number of UE's in an area, this may not always be the case and may change with time.

From the above discussion, it should be appreciated that there is a need for methods and/or apparatus for dynamically allocating resources for pilot transmissions which results in efficient utilization of resources for pilot signal transmissions.

SUMMARY

Methods and apparatus that facilitate efficient use of communications resources, e.g., resources which can be used to transmit pilot signals are described. Various features facilitate handover related measurements and efficient allocation of resources which can be used for handover related measurements in a communications system including user equipment (UE) devices, e.g., wireless terminals, a macro base station (e.g., an eNodeB also referred to as eNB) and small base stations, e.g., femtocells or picocells. Some of the features described in various embodiments are well suited for systems with dense deployment of small base stations, for example, in an area where the number of small base stations, e.g., femto cells and/or picocells, is comparable to or exceeds the number of active UEs (user equipment devices) in an area. In at least some LTE embodiments the active UEs are considered to be the UEs which are RRC_connected UEs.

In accordance with one aspect of some embodiments a macro base station allocates periodic communications resources for transmission of wideband signals, e.g., pilot signals, by active UE devices, and/or by small base stations. The periodic communications resources for active UEs are allocated in an uplink (UL) band while the periodic resources for small base stations are allocated in a downlink (DL) band. In some embodiments, the periodic communications resources for both active UEs and for small base stations are allocated in same (DL or UL) band. In some embodiments at any given time the macro base station allocates resources for pilot signal transmissions by UEs or pilot signal transmissions by small base stations but not both with the macro base station controlling whether the UEs or small base stations will perform pilot signal transmissions during any given time period.

In some by not necessarily all embodiments the macro base station configures either small cells or active UEs to transmit in the allocated communications resources based on the density of the small cells and the density of the active UEs in the macro cell where the active UEs and the small cells are within the coverage area of the macro base station. In some embodiments the macro base station (eNB) configures the active UEs to transmit pilot signals using the handover resources, e.g., pilot signal communications resources, if the number of UEs in an area, e.g., a macro cell coverage area corresponding to the macro cell, is smaller than the number small cells in the area. In some such embodiments, the small cells are configured to receive the signals transmitted by the active UEs using the handover resources when the handover resources are to be used by the UEs for pilot signal transmissions rather than the small cells. Alternatively, in some embodiments, e.g., if the number of active UEs is greater than the number of the small cells, the macro cell (eNB) configures the small cells in the area, e.g., macro cell coverage area, to transmit pilot signals in the handover resources. In such a case the active UEs are configured to receive the signals transmitted by the small cells using the handover resources.

In some embodiments when active UEs are configured to transmit pilots, the small cells under the coverage area of the macro base station are controlled not to transmit pilots in the allocated communications resources dedicated for pilot transmissions. Furthermore, in at least some embodiments the small cells do not schedule any UE transmissions on the periodic resources allocated for pilot transmissions. In at least some such embodiments UE's may select the pilot signal resources to use for pilot signal transmission and may transmit a device identifier as part of the pilot signal transmission so that other devices can identify the source of the pilot signal. In other embodiments, devices may know which of a plurality of pilot signal resources they are to use based on their device identifier.

The configuration can change dynamically in time and space with the macro base station controlling whether UEs or small cells are to transmit pilot signals during a given time period. In addition the macro base station may control and/or alter the amount of pilot signal transmission resources available for use during a given time period, e.g., based on the number of small cells and/or UEs in an area. The macro base station can, and in some embodiments does, transmit, e.g., broadcast, information indicating whether small base stations or UEs are to transmit pilots during a period of time and/or the information indicating the communications resources dedicated for such signal transmissions. Based on the transmitted information the UEs will either monitor for or transmit pilots. For example, if the pilot signal resources are dedicated for use by UE pilot signal transmissions, the UEs will transmit pilots. However, if the pilot signal resources are dedicated for small base station pilot signal transmissions, the small base stations will transmit pilots and the UEs will monitor for the pilot signal transmissions.

An exemplary method of operating a first base station (e.g., macro base station) corresponding to a cell having a coverage area in which a small base station, e.g., femto or pico base station, is located, in accordance with one embodiment comprises: allocating communications resources for pilot signal transmissions by any of a plurality of small base stations or UE devices, said allocated communications resources being dedicated for pilot signal transmissions; determining whether small base stations or UE devices should use said allocated communications resources for pilot signal transmissions; and communicating information to at least one of said small base station or a UE device indicating the communications resources allocated for pilot signal transmissions.

An exemplary first base station (e.g., a macro base station) corresponding to a cell having a coverage area in which a small base station is located, in accordance with one embodiment comprises at least one processor configured to: allocate communications resources for pilot signal transmissions by any of a plurality of small base stations or UE devices, said allocated communications resources being dedicated for pilot signal transmissions; determine whether small base stations or UE devices should use said allocated communications resources for pilot signal transmissions; and communicate information to at least one of said small base station or a UE device indicating the communications resources allocated for pilot signal transmissions. The first base station may, and in some embodiments does, include a memory coupled to the at least one processor.

In at least some embodiments an exemplary method of operating a small base station, e.g., a femtocell or a picocell, includes receiving information indicating the communication resources dedicated for pilot transmissions, determining communications resources dedicated for use in transmitting pilot signals to UE devices or receiving pilot signals from UE devices, and determining, possibly based on the received) information, whether base stations are to transmit pilot signals on the dedicated communications resources or UE devices are to transmit pilot signals using the dedicated communications resources. In at least some such embodiments the resources dedicated by the macro cell for pilot transmissions by one of small base stations or UE devices is used by either the small base stations or UE devices but not both at the same time.

An exemplary small base station implemented in accordance with one exemplary embodiment comprises at least one processor configured to determine whether communications resources dedicated for pilot signal transmissions are for use by small base stations in transmitting pilot signals to UE devices or are for use in receiving pilot signals from UE devices and receive information, e.g., a signal from a macro base station indicating whether small base stations are to transmit pilot signals on the dedicated communications resources or UE devices are to transmit pilot signals using the dedicated communications resources.

One exemplary method of operating a user equipment (UE) device in accordance with one exemplary embodiment comprises: receiving information indicating the communication resources dedicated for pilot transmissions, determining communications resources dedicated for use in transmitting pilot signals to base stations or receiving pilot signals from base stations; and determining, possibly based on the received information, whether base stations are to transmit pilot signals on said dedicated communications resources or UE devices are to transmit pilot signals using said dedicated communications resources.

An exemplary user equipment device in at least some embodiments includes at least one processor configured to determine whether a set of communications resources, e.g., pilot signal transmission resources, are dedicated for use in transmitting pilot signals to base stations or for use in receiving pilot signals from base stations and to receive information, e.g., a broadcast signal from a base station, indicating whether base stations, e.g., small base stations, are to transmit pilot signals on the dedicated communications resources or if UE devices are to transmit pilot signals using said dedicated communications resources. The user equipment device may, and in some embodiments does, include a memory coupled to the at least one processor.

While various embodiments have been discussed in the summary above, it should be appreciated that not necessarily all embodiments include the same features and some of the features described above are not necessary but can be desirable in some embodiments. Numerous additional features, embodiments and benefits of various embodiments are discussed in the detailed description which follows.

BRIEF DESCRIPTION OF THE FIGURES

FIG. **1** illustrates an exemplary wireless communications system implemented in accordance with one exemplary embodiment.

FIG. **2** is a flowchart illustrating an exemplary method of operating a first base station of the system shown in FIG. **1**, in accordance with one exemplary embodiment.

FIG. **3** illustrates an exemplary first base station, e.g., eNodeB, which can be used as the macro base station shown in the exemplary system of FIG. **1**.

FIG. **4** illustrates an assembly of modules which can be used in the exemplary first base station shown in FIG. **3**.

FIG. **5**, which comprises a combination of FIGS. **5**A and **5**B, is a flowchart illustrating an exemplary method of operating a base station of the system shown in FIG. **1**, in accordance with one exemplary embodiment.

FIG. **6** illustrates an exemplary base station, e.g., femto or pico base station, station which can be used as any one of the small base stations shown in the exemplary system of FIG. **1**.

FIG. **7** illustrates an assembly of modules which can be used in the exemplary base station shown in FIG. **6**.

FIG. **8** illustrates an exemplary measurement report which may be communicated, e.g., from a base station or user equipment device, to a macro base station or a central control node, in accordance with an exemplary embodiment.

FIG. **9**, which comprises a combination of FIGS. **9**A and **9**B, is a flowchart illustrating an exemplary method of operating a user equipment device of the system shown in FIG. **1**, in accordance with one exemplary embodiment.

FIG. **10** illustrates an exemplary user equipment device which can be used as any one of the user equipments (UEs) shown in the exemplary system of FIG. **1**.

FIG. **11** illustrates an assembly of modules which can be used in the exemplary user equipment device shown in FIG. **10**.

FIG. **12** illustrates a set of steps used in some embodiments to determine whether base stations or UE devices are to transmit pilot signals using communications resources dedicated for use in sending pilot signals.

DETAILED DESCRIPTION

FIG. **1** illustrates an exemplary communications system **100** including a base station **124**, e.g., a macro base station, with a coverage area represented by cell **1 161**, a plurality of user equipment devices (UEs), e.g., wireless terminals, including UE **1 102**, UE **2 104**, UE **3 106** through UE N **110**, and a plurality of small base stations also called small cells including small base station **1 112**, small base station **2 114**, small base station **3 116**, through small base station K **120**.

Each small base station may be, e.g., a femtocell or a picocell. The base station **124** is a macro base station (also referred to as macro cell) and serves as an attachment point for at least some of the UEs in its coverage area, e.g., cell **161**. The macro base station **124** may, and in some embodiments is, implemented as an eNodeB. Femto cell is intended to be a term which is not technology specific and can be used to refer to any of a wide range of different types of femto cells. The coverage area of the small base stations is normally much smaller, e.g., less than 50% of the coverage area of the macro base station. Thus, as shown in FIG. **1**, multiple small base stations may be within the coverage area of a single macro base station **124**. The femto cells in the present application are not intended to be limited to a particular technology unless expressly identified using a technology specific term. Femto cells may be implemented as HeNB (Home eNode B) cells in LTE while in 3GPP terminology a Home Node B (HNB) is a femto cell. In some but not necessarily all embodiments, a femto cell has a range (radius) of the order of 10 meters while a picocell has a range that is 200 meters or less. This is considerably smaller than the typical range of a macro cell which may have, and sometimes does have, a range up to 35 kilometers (approximately 22 miles). While such a large range is possible for a macro base station, smaller ranges are often used for macro base station **124**. Small cells may include, in addition to femto cells and pico cells other types of small cells. For example the term microcell is used by some companies to refer to a base station with a range of approximate 12 meters. Thus, while the term micro cell is used by some companies to refer to their femto cells, such cells are to be considered small cells for purposes of the discussion included in the present application.

In addition to the base stations and the UEs, system **100** further includes a mobility management entity (MME) **160** and a control node **130**, e.g., a central control entity such as a radio network controller. System **100** may include a plurality of other macro base stations with corresponding coverage areas as illustrated in the figure by cell M **171**. Cell M **171** may be similar to cell **1 161** and may include a plurality of UE devices and small base stations in addition to a macro base station to which the coverage area illustrated by cell M **171** corresponds. In some embodiments the macro base station **124** and small base stations exchange signaling and information with the MME device **160** to facilitate tracking of the locations of mobile devices and/or to support or provide other communications services, e.g., paging and/or location based services to the UE devices in the system **100**. While a single MME **160** is shown in FIG. **1**, it should be appreciated that the system **100** may include multiple MMEs.

In various embodiments the UEs shown in FIG. **1** support Wide Area Network (WAN) communications, e.g., cellular network communications through base stations, as well as peer to peer communications, e.g., direct device to device communications. In some, but not necessarily all, embodiments, one or more UE devices are implemented as portable communications devices such as handheld cell phones or portable personal data assistant (PDA) devices. Various base stations (e.g., macro and small base stations) and/or the other infrastructure elements such as the control node **130** and MME **160**, in some embodiments, are coupled via a backhaul link, to one another and/or to other infrastructure nodes for exchanging information. The backhaul link may be a wired or wireless link.

In accordance with one aspect of some embodiments, the macro base station **124** allocates periodic communications resources (time and frequency resources) for transmission of pilots and device identification information by the UE devices or the small base stations, e.g., in the coverage area of the macro base station. In some embodiments part of the identification information may determine the pilot sequence transmitted by the UE devices or the small base stations. The communications resources can be used by a device to transmit a pilot signal. In some embodiments, e.g., where UE devices can select which dedicated pilot signal resources to use, the UE device normally transmits a pilot, e.g., one or more reference signals transmitted on different tones, along with device identification information so that a device receiving the pilots can identify which UE transmitted the pilots. Thus, while the pilot resources are dedicated to communicating pilot signals and/or corresponding information, e.g., information identifying the transmitting device, the resources may be used autonomously on a contention basis with different UE's and/or small base stations contending amongst themselves to use the resources since they are not dedicated to a specific individual device in some embodiments.

In some embodiments, at any given time, the macro base station **124** configures either the UE devices or the small base stations, but not both, to transmit pilot signals using the allocated periodic communications resources, e.g., in the coverage area of the macro base station **124**. The decision of whether UE devices or small base stations are to transmit pilot signals is based on, e.g., the number and/or density of small base stations in the macro cell coverage area and/or the number or density of active UE devices (i.e., non idle UEs) in the coverage area of the macro base station **124**. The decision of whether UE devices or small base stations are to transmit, in some embodiments, is based on the number of small base stations relative to the number of active UE devices in an area. In accordance with one aspect of some embodiments when there is a dense deployment of small base stations, e.g., the number of small base stations K is comparable to or exceeds the number of active UEs N in the area (e.g., K≥N) the macro base station **124** configures the active UE devices to transmit pilots using the allocated periodic communications resources while configuring the small base stations to receive the pilot signals transmitted by the UE devices on the allocated periodic communications resources and controls the small base stations to refrain from transmitting pilots. In some embodiments when the number of active UE devices is greater than the number of small base stations in the area (e.g., N>K) the macro base station **124** configures the small base stations to transmit pilots using the allocated periodic communications resources while configuring the active UE devices to refrain from transmitting pilots and to receive the pilot signals transmitted by the small cells on the allocated periodic communications resources.

Thus, in at least some embodiments, the macro base station **124** makes the decision of whether UEs or small base stations should transmit pilot signals in a manner which is intended to minimize the number of devices, in addition to the macro base station **124**, that will be transmitting pilots during a given time interval. It should be noted that regardless of whether UEs or small cells transmit pilots the macro base station **124** will transmit pilots in the usual manner. The decision of whether UEs or small base stations should transmit pilots is made by the macro base station **124**, e.g., on a recurring basis, e.g., periodically or when a change in the number of small base stations or active UEs in the macro base station coverage area or a portion of the macro base station coverage area is detected. In some embodiments the decision whether the small base stations or UE devices are to transmit pilots is also based on the current configuration, e.g. the macro base station can have hysteresis in switching to other configuration to avoid ping pong effect. In some embodiments if macro base station has determined that the UE devices are to transmit pilot signals, then it determines that the small base stations are to transmit pilots if the ratio of number of active UE devices (N) to the number of small base stations (K) exceeds a first threshold. Similarly if macro base station has determined that the small base stations are to transmit pilot signals, then it determines that UE devices are to transmit pilots if the ratio of number of active UE devices (N) to the number of small base stations (K) is below a second threshold. In some embodiments the first and second thresholds may depend on the number of UE devices and the number of small base stations.

The amount of resources dedicated for pilot signal transmissions by entities other than the macro base station can be, and sometimes is reconsidered and changed in response to a change in the number of small base stations or active UE devices in an area. Thus, in at least some embodiments the macro base station can and does vary the amount of resources dedicated to pilot signal transmissions at different points in time. In some embodiments, determining the amount of resources to allocate for pilot signal transmission is performed by the same module and/or component of the macro base station which decides whether UE devices or small base stations should transmit pilots.

A transmitting device (e.g., UE devices or the small base stations depending on the configuration specified by the macro base station **124**) selects communications resource(s) from the allocated communications resources, e.g., dedicated pilot signal resources, and transmit pilots along with identification information using the selected transmission resource(s), e.g., periodically. Thus, selection of which pilot signal resource to use from the set of dedicated resources is normally made autonomously by the device, e.g., small base station or UE device, which is to transmit the pilot signal. The chance of a collision is reduced in cases where the macro base station allocates sufficient resources to avoid or minimize collisions and by the macro base station's selection between small base stations and UE devices to transmit pilots, e.g., by making a selection likely to minimize the number of devices transmitting pilot signals. The devices configured to receive the pilot signals (UE devices or the small base stations depending on the configuration set by the macro base station **124**) perform measurements, e.g., received signal strength and/or other signal measurements, and report the measurement results and corresponding device identifiers to, e.g., the base station **124** or a control node **130**. In some embodiments the macro base station or the control node uses the received report to make handover decisions.

While some examples discussed above have been used to describe various features, the method used in some embodiments will become even clearer when considered in view of the flow charts shown in FIGS. **2**, **5** and **9**.

FIG. **2** is a flowchart **200** showing the steps of an exemplary method of operating a first base station, e.g., a macro base station, corresponding to a cell having a coverage area in which a small base station is located, in accordance with an exemplary embodiment. In some embodiments the first base station implementing the method of flowchart **200** is e.g., the macro base station **124** shown in FIG. **1**. The first base station **124** may, and in some embodiments is, implemented as an eNodeB. For the purposes of discussion consider that BS **124** is the first base station implementing the method of flowchart **200**. In some embodiments the small base station is a femtocell or a picocell. In some embodiments the small base station has a coverage area less than one half the coverage area of the first base station.

Operation starts in step **202**. In step **202** the first base station is powered on and initialized. Operation proceeds from start step **202** to step **204**. In step **204** the first base station determines a number of small base stations and a number of active user equipment (UE) devices in a coverage area of the first base station, e.g., cell **1 161** shown in FIG. **1**. In some embodiments, the information indicating the determined number of small base stations and a number of active user equipment (UE) devices in a coverage area of the first base station is stored by the first base station, e.g., in memory. It should be noted that some of the active UE devices may not be attached to the first base station and may be attached to some of the plurality of small base stations in the coverage of the first base station.

Following the determination of the number of small base stations and active UEs operating in the coverage area, in some embodiments the first base station dedicates a group of periodic communications resources for pilot transmissions by devices in the coverage area of the first base station. Operation proceeds from step **204** to steps **206** and **208** which may be, and in some embodiments are, performed asynchronously. In step **206**, the first base station **124** allocates communications resources for pilot transmissions by any of a plurality of small base stations or UE devices, the allocated communications resources being dedicated for pilot transmissions, the small base station being one of the plurality of small base stations. Operation proceeds from step **206** to step **210** where the first base station refrains from using the allocated communications resources to transmit signals and/or for other purposes, e.g., first base station does not use/assign the allocated resources for any other uplink/downlink communications. Thus in some embodiments the first base station refrains from scheduling data transmissions (e.g., by UE devices) in the allocated communications resources.

The communications resources for pilot transmissions may be, and in some embodiments are, allocated in different carriers or across a set of carriers to allow for wide band pilot signal transmissions. Thus, a receiving device can make a reasonable estimate of interference across the set of frequencies the transmissions of the device transmitting the pilot signal(s) is likely to encounter as well as make received signal strength measurements, such as SNR measurements for multiple frequencies. While the pilots may be wideband, the communication resources dedicated for their transmission will normally correspond to the frequency band the transmitting device uses for transmission purposes. For example in some embodiments the communications resources are allocated, when small base stations are to transmit pilots, in a frequency band in which the small cells transmit, e.g., in a downlink frequency band. However, when UE's are to transmit pilots, the macro base station **124** allocates the communications resources to be used for UE pilot signal transmissions in the frequency band in which the UEs transmit, e.g., uplink frequency band. Thus, in frequency division duplex (FDD) systems where uplink and downlink use separate frequency bands, the frequency band in which the macro base station **124** allocates resources for non-macro base station pilot signal transmissions will vary depending on whether UEs or small base stations are to transmit pilots. In time division duplex (TDD) systems where uplink and downlink use the same frequency bands at different times, the time period in which resources are allocated for pilot signal transmissions will vary depending on whether small base stations are to transmit pilots or UEs are to transmit pilots. In a TDD system resources will be dedicated in the downlink transmission time period when small base stations are to transmit pilots while pilot signal transmission resources during the uplink time period will be allocated by the macro base station **124** when UE devices are to transmit pilots. In some embodiments the macro base station may allocate the same set of resources for pilot transmissions irrespective of whether small base stations or UE devices are to transmit pilot signals.

In some embodiments, when resources are allocated in the uplink band for UE pilot transmissions, the macro base station and small base stations refrain from using the allocated communications resources for any other purposes, e.g., they do not assign the allocated resources from the uplink band for any other uplink communications. Similarly, in some embodiments when resources are allocated in the downlink band for pilot transmission by small base stations, the macro base station **124** and small base stations refrain from using the allocated communications resources from the downlink band for any other purposes other than transmitting pilot signals and related information, e.g., device identification information that is transmitted with the pilot signals.

Operation proceeds from step **210** to step **212**. In step **212** the first base station determines whether the small base stations or the UE devices in the coverage area should use the allocated communications resources dedicated for pilot transmissions. In various embodiments, as part of performing step **212**, one or more of the steps **214**, **216**, **218** and **220** are performed. In accordance with one aspect, the decision whether the small base stations or the UEs in the coverage area of the first base station should use the allocated resources for transmitting pilot signals at a given time depends on the number of the small base stations and the number of active UE devices in the coverage area at the given time. Accordingly, the first base station makes this determination based on the knowledge of the number of the small base stations and active UE devices in the coverage area at that time. Thus as illustrated in step **214**, the first base station compares the number of small base stations to the number of active UE devices in the coverage area of the first base station. The decision as to which devices should be selected to transmit pilot signals is made in step **216**, which is performed as part of step **214**, and the selection is made according to the decision. If the number of active UE devices is less than the number of small base stations in the coverage area of the first base station, then step **218** is performed wherein the first base station selects the UE devices to transmit the pilot signals. If the number of small base stations is less than the number of active UE devices in the coverage area of the first base station, then step **220** is performed where the first base station selects the small base stations to transmit the pilot signals.

In an alternative embodiment, step **212'** illustrated in FIG. **12** is performed in place of step **212**. Referring to FIG. **12**, as illustrated in drawing **1200**, in step **212'** the first base station determines whether the small base stations or the UE devices in the coverage area should use the allocated communications resources dedicated for pilot transmissions. In the illustrated embodiment, as part of performing step **212'**, one or more of the steps **214'**, **216'**, **218'** and **220'** are performed. As illustrated in step **214'**, the first base station computes a ratio of the number of small base stations devices in the coverage area of the first base station to the number of active UE devices in the coverage area of the first base station. Next in step **216'** a comparison is made to determine if the computed ratio is above a first threshold. If the computed ratio is above the first threshold, then step **218'** is performed wherein the first base station selects the UE devices to transmit the pilot signals. If the computed ratio is below the first threshold, then step **220'** is performed where the first base station selects the small base stations to transmit the pilot signals.

Operation proceeds from step **212** (or step **212'** depending on the embodiment) to step **222**. In step **222** the first base station communicates resource allocations and use related information, e.g., to at least one of the small base stations or the UE devices. In some embodiments steps **224** and **226** are individually performed as part of step **222**. In step **224** the first base station communicates information to at least one small base station or a UE device indicating the communications resources allocated for pilot signal transmissions. In step **226** the first base station transmits information indicating a decision whether the small base stations or UE devices are to transmit the pilot signals using the allocated communications resources. In some embodiments the information regarding the allocated resources indicated in step **224** and the information regarding the decision indicated in step **226** is transmitted in a single message while in some embodiments the information is communicated via separate individual messages from the first base station. Operation proceeds from steps **224** and **226** back to step **206**.

Returning now to step **208**, in various embodiments following the initial determination of the number of small base stations and active UE devices in the coverage area of the first base station, the first base station monitors to detect any change in the determined number of small base stations or active UE devices in its the coverage area, e.g., on an ongoing basis. In step **208** the first base station detects a change in at least one of the number of small base stations or active UE devices in the coverage area of the first base station. Operation proceeds from step **208** to step **228**. In step **228** the first base station updates the information indicating the number of small base stations and the number of active user equipment (UE) devices in the coverage area of the first base station, e.g., based on the detected change in the number of devices. Thus the updated information reflects a new number of small base stations and the number of active user equipment (UE) devices in the coverage area of the first base station.

Operation proceeds from step **228** to step **230**. In step **230** the first base station changes at least one of a duration or frequency of resources allocated for pilot signal transmission in response to a change in at least one of the number of small base stations or the number of active user equipment (UE) devices in the coverage area of the first base station. Thus in various embodiments the first base station changes at least one characteristic corresponding to the communications resources allocated for pilot transmissions based on the detected change in the number of small base stations or the active UE devices in the coverage area of the first base station. For example in some embodiments when it is determined that the number of small base stations exceeds the number of active UEs in the coverage area, the communications resources are allocated for uplink communication in an uplink frequency band in which the active UEs transmit pilot signals and device identification information via the allocated resources and the small cells receive via the allocated resources. In some other embodiments, when the number of UE devices exceeds the number of small base stations in the coverage area the communications resources are allocated for downlink communication in a downlink frequency band in which the small base stations transmit pilot signals and identification information via the allocated resources and the UEs receive via the resources.

Operation proceeds from step **230** back to steps **206** and **208** and the operation continues in this manner. In various embodiments steps **208**, **228** and **230** are performed on an ongoing basis. Thus when a change in at least one of the number of small base stations or active UE devices in the coverage area is detected, information indicating the number of devices is updated and the first base station changes at least one of a duration or frequency of resources allocated for pilot signal transmission in response as discussed above.

It should be appreciated that in some embodiments in the next iteration, updated information indicating the new number of small base stations and the number of active user equipment (UE) devices in the coverage area of the first base station is used to repeat steps **212** and **222**.

FIG. **3** is a drawing of an exemplary communications device **300**, e.g., a first base station, in accordance with various embodiments. Exemplary first base station **300** can be used as the base station **124**, shown in system **100** of FIG. **1**. Exemplary first base station **300** can, and sometimes does, allocate communications resources to the small base stations and/or the UE devices in the coverage area of the base station **300** for pilot signal transmissions. The first base station **300** may, and sometimes does, implement a method in accordance with flowchart **200**.

The first base station **300** includes a processor **302** and memory **304** coupled together via a bus **309** over which the various elements (**302**, **304**) may interchange data and information. The first base station **300** further includes an input module **306** and an output module **308** which may be coupled to processor **302** as shown. However, in some embodiments, the input module **306** and output module **308** are located internal to the processor **302**. Input module **306** can receive input signals. Input module **306** includes a wireless receiver module **320** for receiving input including over wireless communications links. Input module **306** also includes a wired and/or optical input receiver module **322** for receiving input over a wired and/or optical link. Output module **308** includes a wireless transmitter module **326** for transmitting output signals over wireless communications links. Output module **308** also includes a wired and/or optical output transmitter module **328** for transmitting output signals over a wired and/or optical link. Memory **304** includes routines **311**, and data/information **313**.

The first base station **300** further includes wireless communications receive antenna **324** coupled to wireless receiver module **320** and wireless communications transmit antenna **330** coupled to wireless transmitter module **326**. In some embodiments, the same antenna is used for both input and output wireless communications signaling. The wired and/or optical receiver module **322** and the wired and/or optical transmitter module **328** are coupled to other nodes and/or a backhaul via link **332**.

In various embodiments, processor **302** is configured to determine a number of small base stations and a number of user equipment (UE) devices in a coverage area of the first base station, and store the information indicating the determined number of small base stations and a number of user equipment (UE) devices in a coverage area of the first base station, e.g., in the memory **304**.

In various embodiments, processor **302** is configured to dedicate some communications resources, e.g., set aside from the available communications resources, for pilot transmissions by devices in the coverage area of the first base station. In various embodiments the processor **302** is further configured to allocate communications resources for pilot transmissions by any of a plurality of small base stations or UE devices, the allocated communications resources being dedicated for pilot transmissions, and refrain from using the allocated communications resources for any other purposes, e.g., the processor **302** controls the first base station to not use/assign the allocated resources for any other uplink/downlink communications.

In various embodiments the processor **302** is further configured to determine whether the small base stations or the UE devices in the coverage area should use the allocated communications resources dedicated for pilot transmissions, e.g., at a given time. In various embodiments, as part of being configured to determine whether the small base stations or the UEs in the coverage area of the first base station should use the allocated resources for transmitting pilot signals at a given time, the processor **302** is further configured to compare the number of small base stations to the number of UE devices in the coverage area of the first base station, decide as to which device should be selected to transmit pilots signals and which one to receive the pilot signals based on the comparison. The processor **302** is further configured to: select the UE devices to transmit the pilot signals when the comparison indicates that the number of UE devices is less than the number of small base stations in the coverage area of the first base station **300**, and select the small base stations to transmit the pilot signals if the number of small base stations is less than the number of UE devices in the coverage area of the first base station.

In various embodiments the processor **302** is further configured to control the first base station **300** to communicate (e.g., transmit via output module **308**) resource allocations and use related information, e.g., to at least one of the small base stations or the UE devices. In some embodiments the processor is configured, as part of being configured to communicate resource allocations and use related information, to communicate (e.g., transmit via output module **308**) information to at least one small base station or a UE device indicating the communications resources allocated for pilot signal transmissions, and transmit information indicating a decision whether the small base stations or UE devices are to transmit the pilot signals using the allocated communications resources. In some embodiments the processor **302** is configured to control the output module **308**, e.g., transmitter **326**, to transmit the information regarding the allocated resources and the information regarding the decision whether the small base stations or UE devices are to transmit the pilot signals, in a single message while in some other embodiments the processor **302** is configured to control the transmitter to communicate such information via separate individual messages from the first base station **300**.

In some embodiments the processor **302** is further configured to monitor to detect any change in the number of small base stations or UE devices in its the coverage area, e.g., on an ongoing basis, and update the information indicating the number of small base stations and the number of user equipment (UE) devices in the coverage area of the first base station when a change in the number of devices is detected. Thus in some embodiments the processor **302** updates the previously stored information to reflect the new number of small base stations and the number of user equipment (UE) devices in the coverage area of the first base station **300**. In some embodiments the processor **302** is further configured to change at least one of a duration or frequency of resources allocated for pilot signal transmission in response to a change in at least one of the number of small base stations or the number of user equipment (UE) devices in the coverage area of the first base station.

In various embodiments the processor **302** is configured to control the operation of the first base station and perform one or more steps on an ongoing basis using the updated information indicating the number of small base stations and UE devices in the coverage area of the first base station **300**. For example in some embodiments the processor **302** is further configured to repeat, using updated information indicating the new number of small base stations and the number of user equipment (UE) devices in the coverage area of the first base station, the following operations: determine whether small base stations or UE devices should use said allocated communications resources for pilot signal transmissions; and transmit information indicating whether the small base stations or UE devices are to transmit pilot signals using said allocated communications resources. In various embodiments the first base station **300** is a macro base station. In various embodiments a small base station is a femtocell or picocell. In some embodiments at least some of the small base stations have a coverage area less than one half the coverage area of the first base station **300**.

FIG. **4** is an assembly of modules **400** which can, and in some embodiments is, used in the exemplary first base station **300** illustrated in FIG. **3**. The modules in the assembly **400** can, and in some embodiments are, implemented in hardware fully within the processor **302** of FIG. **3**, e.g., as individual circuits. In other embodiments some of the modules are implemented, e.g., as circuits, within the processor **302** with other modules being implemented, e.g., as circuits, external to and coupled to the processor. As should be appreciated the level of integration of modules on the processor and or with some modules being external to the processor may be one of design choice. In some but not necessarily all embodiments modules **404**, **406**, **408**, **410**, **412**, **414**, **418**, **420**, **428**, **430**, and **432** are implemented in the processor with the other modules being implemented in the processor and/or external to the processor **302**.

Alternatively, rather than being implemented as circuits, all or some of the modules may be implemented in software and stored in the memory **304** of the first base station **300** shown in FIG. **3** with the modules controlling operation of the first base station **300** to implement the functions corresponding to the modules when the modules are executed by a processor, e.g., processor **302**. In some such embodiments, the assembly of modules **400** is included in routines **311** of memory **304** of device **300** of FIG. **3**. In still other embodiments, various modules are implemented as a combination of hardware and software, e.g., with a sensor or another circuit external to the processor **302** providing input to the processor **302** which then under software control operates to perform a portion of a module's function.

While shown in the FIG. **3** embodiment as a single processor, e.g., computer, it should be appreciated that the processor **302** may be implemented as one or more processors, e.g., computers. When implemented in software the modules include code, which when executed by the processor, configure the processor, e.g., computer, **302** to implement the function corresponding to the module. In some embodiments, processor **302** is configured to implement each of the modules of the assembly of modules **400**. In embodiments where the assembly of modules **400** is stored in the memory **304**, the memory **304** is a computer program product comprising a computer readable medium, e.g., a non-transitory computer readable medium, comprising code, e.g., individual code for each module, for causing at least one computer, e.g., processor **302**, to implement the functions to which the modules correspond.

Completely hardware based or completely software based modules may be used. However, it should be appreciated that any combination of software and hardware (e.g., circuit implemented) modules may be used to implement the functions. As should be appreciated, the modules illustrated in FIG. **4** control and/or configure the first base station **300** or elements therein such as the processor **302**, to perform the functions of the corresponding steps illustrated and/or described in the method of flowchart **200** of FIG. **2**.

Assembly of modules **400** includes a module **404** configured to determine a number of small base stations and a number of user equipment (UE) devices in a coverage area of the first base station, a module **406** configured to allocate communications resources for pilot transmissions by any of a plurality of small base stations or UE devices, the allocated communications resources being dedicated for pilot transmissions, a module **408** configured to monitor and detect any change in the number of small base stations or UE devices in its the coverage area, and a module **410** configured to control the first base station to refrain from using the allocated communications resources to transmit signals and/or for other purposes, e.g., the module **410** controls the first base station **300** to not use/assign the allocated resources for any other uplink/downlink communications. Thus in some embodiments the module **410** control the first base station to refrain from scheduling data transmissions (e.g., by UE devices) in the allocated communications resources.

In various embodiments the assembly of modules **400** further includes a module **412** configured to determine whether the small base stations or the UE devices in the coverage area should use the allocated communications resources dedicated for pilot transmissions. In various embodiments, the module **412** includes a module **414** configured to compare the number of small base stations to the number of UE devices in the coverage area of the first base station and decide as to which device should be selected to transmit pilots signals and which one to receive the pilot signals based on the comparison, a module **418** configured to select the UE devices to transmit the pilot signals when the comparison indicates that the number of UE devices is less than the number of small base stations in the coverage area of the first base station **300**, and a module **420** configured to select the small base stations to transmit the pilot signals if the number of small base stations is less than the number of UE devices in the coverage area of the first base station.

In various embodiments the assembly of modules **400** further includes a module **422** configured to communicate resource allocations and use related information, e.g., to at least one of the small base stations or the UE devices. In some embodiments the module **422** includes a module **424** configured to communicate, e.g., transmit via output module **308**, information to at least one of the small base stations or the UE devices indicating the communications resources allocated for pilot signal transmissions, and a module **426** configured to transmit, e.g., via output module **308**, information indicating a decision whether the small base stations or UE devices are to transmit the pilot signals using the allocated communications resources.

In some embodiments the assembly of modules **400** further includes a module **428** configured to update the information indicating the number of small base stations and the number of user equipment (UE) devices in the coverage area of the first base station when a change in the number of devices in the coverage area of the first base station is detected, and a module **430** configured to change at least one of a duration or frequency of communications resources allocated for pilot signal transmission in response to a change in at least one of the number of small base stations or the number of user equipment (UE) devices in the coverage area of the first base station **300**.

In some embodiments the assembly of modules **400** further includes a module **432** configured to control the operation of the first base station **300** by controlling one or more modules in the assembly of modules **400** to perform their functions using the updated information indicating a new updated number of small base stations and UE devices in the coverage area of the first base station **300**. For example in some embodiments the module **432** controls the module **412** to repeat the determination operation to determine whether the small base stations or the UE devices should use said allocated communications resources for pilot signal transmissions using updated information indicating the new number of small base stations and the number of user equipment (UE) devices in the coverage area of the first base station, and control the module **426** to transmit information indicating whether the small base stations or UE devices are to transmit pilot signals using said allocated communications resources.

FIG. **5** is a flowchart **500** showing the steps of an exemplary method of operating a small base station, e.g., a femtocell or a picocell, in accordance with an exemplary embodiment. In some embodiments the base station implementing the method of flowchart **500** is any one of the base stations **112**, **114**, **116**, . . . , or **120** shown in FIG. **1**. For the purposes of discussion consider that base station **112** device implements the method of flowchart **500**.

Operation starts in step **502**. In step **502** the base station **112** is powered on and initialized. Operation proceeds from start step **502** to step **504**. In step **504** the base station receives information indicating communications resources that are dedicated for use in transmitting pilot signals to or receive pilot signals from user equipment (UE) devices, e.g., from a macro base station such as base station **124**. In some embodiments step **504** is not performed and the information indicating communications resources that are dedicated for use in transmitting pilot signals may be pre-stored in the base station implementing the method of flowchart **500**.

Operation proceeds from step **504** to step **505**. In step **505** the base station determines the communications resources dedicated for use in transmitting pilot signals to or receive pilot signals from UE devices. The determination is made, e.g., based on the received information or the previously stored information indicating the resources dedicated for use in transmitting or receiving pilot signals as discussed above.

Operation proceeds from step **505** to step **506** which is optional. In step **506** the base station receives information indicating whether base stations are to transmit pilot signals using the dedicated communications resources or UE devices are to transmit pilot signals using the dedicated communications resources. The information is received e.g., from a macro base station or a central control node in some embodiments. In some embodiments the received information includes a mode indicator which indicates to the base station whether the base stations or the UE devices are to transmit pilot signals using the dedicated communications resources. In some embodiments the mode indicator indicates that the base station is to operate in a mode in which the base stations are to transmit pilot signals using the dedicated communications resources.

In some embodiments when no such information indicating whether the base stations or the UE devices are to transmit pilot signals using the dedicated communications resources is received, the base station operates in a default mode which can be pre-configured in some embodiments. For example, in some embodiments in the default mode the base stations are to transmit pilot signals using the dedicated communications resources. In some other embodiments, in the default mode the UE devices are to transmit pilot signals using the dedicated communications resources. In some embodiments the default mode of the base station can be changed, e.g., based on an instruction received from a macro base station and/or a user input.

Operation proceeds from step **506** to step **508**. In step **508** the base station determines, e.g., using the received information indicating which devices (e.g., base stations or UEs) are to transmit pilot signals, whether the base stations or UE devices are to transmit pilot signals using the dedicated communications resources. In various embodiments, as part of determining step **508**, one or more of steps **510**, **512**, **514**, **516**, **518** and **520** are performed. In sub-step **510** the base station determines if a mode indicator has been received, e.g., as part of the received information included in a received wireless signal transmitted by the macro base station. If it is determined that a mode indicator has not been received, the operation proceeds to sub-step **514**. If in step **510** it determined that a mode indicator has been received, the operation proceeds to sub-step **512** where it determined if the received mode indicator indicates a first mode of operation. If it is determined that the mode indicator does not indicate the first mode, operation proceeds from sub-step **512** to sub-step **514** where the base station operates in accordance with a default mode. The base station implementing the method may, and in some embodiments does, store information indicating whether the default mode is one in which base stations are to transmit pilot signals or UE devices are to transmit pilot signals. The macro base station may signal, and in some embodiments does signal, to the small base stations and UE devices what the default mode is to be set to. In such embodiments the receiving devices receive the information and set the default mode to that specified by the macro base station.

Operation proceeds from sub-step **514** to sub-step **516** where the base station determines if the default mode is set to a mode in which base stations are to transmit pilot signals using the dedicated communications resources. If it determined that the default mode is set to a mode in which base stations are to transmit pilot signals the operation proceeds to steps **536** and **538** via connecting node B **524**, otherwise the operation proceeds to step **526** via connecting node A **522**.

Referring again to step **512**, if in step **512** it is determined if the received mode indicator indicates a first mode, the operation proceeds from sub-step **512** to sub-step **518** where the base station operates in accordance with the first mode. Operation proceeds from sub-step **518** to sub-step **520** where the base station determines if the first mode is set to a mode in which base stations are to transmit pilot signals. If in step **520** it is determined that the first mode is set to a mode in which base stations are to transmit pilot signals the operation proceeds to steps **536** and **538** via connecting node B **524**, otherwise it is considered that the first mode is set to a mode in which UE devices are to transmit pilot signals and the operation proceeds to step **526** via connecting node A **522**. In various embodiments the default mode and the first mode are different and can be set/controlled by, e.g., the macro base station that allocates the dedicated communications resources for pilot transmissions, or by the control entity, e.g., control node **130**. In some embodiments in the first mode the UE devices are to transmit pilot signals using the dedicated communications resources.

Thus, depending on whether the base stations or the UE devices are to transmit pilot signals, the operation proceeds along one of two possible processing paths as illustrated.

Consider processing path that continues through node A **522**. As discussed above, before reaching this processing point at connecting node A **522** it has been determined that UE devices are to transmit pilot signals. In step **526** the base stations starts monitoring communications resources, dedicated for use in transmitting pilot signals, for pilot signals transmitted by UE devices. Since the base station already determined (e.g., in step **508**) that the UE devices are to transmit pilot signals using the dedicated resources, it infers that it is to receive pilot signals transmitted by UE devices and thus in step **526** the base station begins monitoring for pilot signal transmissions on the dedicated communications resources.

Operation proceeds from step **526** to step **528**. In step **528** the base station receives a pilot signal from a UE device. Operation proceeds from step **528** to step **530**. In accordance with one aspect of some embodiments, in step **530** the base station performs a measurement to measure the received signal strength of the received pilot signal from the UE device. Operation proceeds from step **530** to step **532**. In step **532** the base station estimates a signal to noise ratio (SNR) to the UE device from which the pilot signal was received. Operation proceeds from step **532** to step **534**. In step **534** the base station generates a measurement report including the measured pilot signal strength and the estimated SNR along with UE device identification information and sends the generated report to one of a base station serving the UE from which the pilot signal was received, e.g., macro base station **124** or to a control node, e.g., radio network controller. In some embodiments macro base station can act as a control node. Operation proceeds from step **534** back to step **504** via connecting node C **552**.

Referring now to steps **536** and **538** along the other processing path that continues through node B **524**. Following a determination that the base stations are to transmit pilot signals using the dedicated communications resources, in step **536** the base station monitors the communications resources dedicated for transmitting pilot signals to identify resources which are unused. In various embodiments the base station monitors the resources to detect/measure energy on the resources. In some embodiments the resources on which least amount of energy or energy below a predetermined threshold is detected are considered unused. Operation proceeds from step **536** to step **540**.

Referring now to step **538**, in step **538** the base station starts monitoring for signals from UE devices, e.g., to determine if one or more UE devices are present in its vicinity. If a signal from one or more UE devices is detected during the monitoring, this indicates that the one or more UE devices from which the signal is detected are present and may be in the vicinity of the base station. These signals from UE devices could be part of their cellular communication, e.g. uplink transmissions to their serving base stations or non-cellular communication, e.g. peer to peer communication. Operation proceeds from step **538** to step **542** and **546**.

In step **540** the base station selects one or more identified unused communications resources from the communications resources dedicated for use in transmitting pilot signals. The base station may autonomously select the communication resource in some embodiments. In some embodiments, the communication resource selected by the base station is determined by the identity of the base station. Operation proceeds from step **540** to step **542**. In step **542** the base station transmits pilot signals and identification information on communications resources included in the communications resources dedicated for use in transmitting pilot signals. In various embodiments step **542** includes step **544** in which the base station transmits pilot signals and identification information on the selected identified unused communications resources as part of transmitting the pilot signals on the communications resources included in the dedicated communications resources. In some embodiments the base station transmits pilot signals at a predetermined power. The timing used to transmit the pilot signals may be derived from the signals received from the macro base station **124**. In some embodiments step **542** is performed on a periodic basis. Operation proceeds from step **542** to step **546**.

In step **546** the base station ceases to transmit pilot signals on the communication resources dedicated for pilot transmissions when a signal from at least one UE device is not detected for a predetermined period of time during the monitoring operation, e.g., the monitoring illustrated in step **538**. Thus in accordance with one feature, the base station stops transmitting pilot signals and identification information when it determines that UE devices are not in the vicinity as indicated by lack of detected signals from a UE device for a predetermined time during the monitoring operation. However it should be appreciated that when the base station continues to detect signals from one or more UEs during the monitoring, the base station continues to transmit the pilot signals, e.g., periodically.

Consider for example that the base station ceased to transmit pilot signals in step **546**. Operation proceeds from step **546** to step **548** which is an optional step. In step **548** the base station receives a signal from a UE device. Operation proceeds from step **548** to step **550**. Following the detection of a signal from a UE device, the base station again resumes the pilot signal transmission operation in step **550**, e.g., as discussed in detail in step **542** and **544**. Operation proceeds from step **550** back to step **504** via connecting node C **552** and the operation may continue in this manner over time.

FIG. **6** is a drawing of an exemplary base station **600**, e.g., a small base station such as a femtocell or picocell, in accordance with various embodiments. Exemplary base station **600** can be used as any one of the base stations **112**, **114**, **116**, . . . , **120** shown in FIG. **1**. Exemplary base station **600** can, and sometimes does, transmit pilot signals and identification information on the communications resources allocated for pilot signal transmissions. The base station **600** may, and sometimes does, implement a method in accordance with flowchart **500**.

The base station **600** includes a processor **602** and memory **604** coupled together via a bus **609** over which the various elements (**602**, **604**) may interchange data and information. The base station **600** further includes an input module **606** and an output module **608** which may be coupled to processor **602** as shown. However, in some embodiments, the input module **606** and output module **608** are located internal to the processor **602**. Input module **606** can receive input signals. Input module **606** includes a wireless receiver module **620** for receiving input including over wireless communications links. Input module **606** also includes a wired and/or optical input receiver module **622** for receiving input over a wired and/or optical link. Output module **608** includes a wireless transmitter module **626** for transmitting output signals over wireless communications links. Output module **608** also includes a wired and/or optical output transmitter module **628** for transmitting output signals over a wired and/or optical link. Memory **604** includes routines **611**, and data/information **613**.

The base station **600** further includes wireless communications receive antenna **624** coupled to wireless receiver module **620** and wireless communications transmit antenna **630** coupled to wireless transmitter module **626**. In some embodiments, the same antenna is used for both input and output wireless communications signaling. The wired and/or optical receiver module **622** and the wired and/or optical transmitter module **628** are coupled to other nodes and/or a backhaul via link **632**.

In various embodiments, processor **602** is configured to receive information indicating communications resources that are dedicated for use in transmitting pilot signals to or receive pilot signals from user equipment (UE) devices, e.g., from a macro base station such as base station **124**, determine the communications resources dedicated for use in transmitting pilot signals to or receive pilot signals from UE devices. In some embodiments the processor **602** is configured to make the determination, e.g., based on the received information or the previously stored information indicating the resources dedicated for use in transmitting or receiving pilot signals as discussed above.

In various embodiments the processor **602** is further configured to receive information indicating whether base stations are to transmit pilot signals using the dedicated communications resources or UE devices are to transmit pilot signals using the dedicated communications resources, and determine whether the base stations or UE devices are to transmit pilot signals using the dedicated communications resources. In some embodiments the received information includes a mode indicator which indicates to the base station whether the base stations or the UE devices are to transmit pilot signals using the dedicated communications resources. In some embodiments the processor **602** is configured to, as part of being configured to determine whether the base stations or UE devices are to transmit pilot signals using the dedicated communications resources, determine whether a mode indicator has been received and control the base station to operate in accordance with the indicated mode. In some embodiments when information indicating whether the base stations or UE devices are to transmit pilot signals and/or a mode indicator is not received, the processor **602** is configured to determine that the base station is to operate in a default mode. Depending on the embodiment, a default mode may be set to a mode in which either the base stations transmit pilot signals using the dedicated communications resources or the UE devices transmit pilot signals using the dedicated communications resources.

In various embodiments when it is determined that the UE devices are to transmit pilot signals using the dedicated resources, in various embodiments the processor **602** is further configured to: monitor communications resources dedicated for use in transmitting pilot signals for pilot signals transmitted by UE devices, control the base station **600** to receive a pilot signal from a UE device, perform measurements to measure the received signal strength of the received pilot signal from the UE device, estimate a signal to noise ratio (SNR) to the UE device from which the pilot signal was received, and control the base station **600** to report a pilot signal strength and an SNR estimate along with UE device identification information to one of a base station serving the UE from which the pilot signal was received or to a control node, e.g., radio network controller. As part of being configured to report, the processor **602** is configured to generate a report including a pilot signal strength, an SNR estimate and UE device identification information and send the generated report to one of a base station serving the UE from which the pilot signal was received or to the control node, e.g., radio network controller.

In various embodiments when it is determined that the base stations are to transmit pilot signals using the dedicated resources, the processor **602** is further configured to: monitor for signals from UE devices, monitor the communications resources dedicated for transmitting pilot signals to identify resources which are unused, select one or more identified unused communications resources from the communications resources dedicated for use in transmitting pilot signals, and control the base station **600** to transmit pilot signals and identification information on communications resources included in the communications resources dedicated for use in transmitting pilot signals. In some embodiments the processor **602** is configured to measure energy on the communications resources to identify the unused dedicated resources. In some embodiments the processor **602** is further configured to identify communications resources on which least amount of energy or energy below a predetermined threshold is detected as the unused communications resources. In various embodiments the processor **602** is further configured to control the base station **600** to transmit pilot signals and identification information on the selected identified unused communications resources as part of being configured to control transmission of the pilot signals on the communications resources included in the dedicated communications resources. In some embodiments the processor is configured to control the base station **600** to control transmission of the pilot signals on the selected identified resources periodically.

In some embodiments the processor **602** is further configured to control the base station **600** to cease transmitting pilot signals when a signal from at least one UE device is not detected for a predetermined period of time during the monitoring operation. In some embodiments the processor **602** is further configured to control the base station **600** to receive a signal from a UE device, and resume the pilot signal transmission operation following the detection of the signal from the UE device. Thus the processor **602** is configured to resume and continue transmitting the pilot signals, e.g., periodically, when the signals are detected from one or more UEs during the monitoring.

FIG. **7** is an assembly of modules **700** which can, and in some embodiments is, used in the exemplary base station **600** illustrated in FIG. **6**. The modules in the assembly **700** can be implemented in hardware within the processor **602** of FIG. **6**, e.g., as individual circuits. The modules in the assembly **700** can, and in some embodiments are, implemented fully in hardware within the processor **602**, e.g., as individual circuits. In other embodiments some of the modules are implemented, e.g., as circuits, within the processor **602** with other modules being implemented, e.g., as circuits, external to and coupled to the processor. As should be appreciated the level of integration of modules on the processor and/or with some modules being external to the processor may be one of design choice. In some but not necessarily all embodiments some of the modules discussed below, e.g., modules **705**, **708**, **726**, **736**, **738**, **730**, **732**, **740**, **746**, **748**, and **750** are implemented in the processor **602** with the other modules, e.g., modules **704**, **706**, **734**, **742** etc., being implemented in the processor and/or external to the processor.

Alternatively, rather than being implemented as circuits, all or some of the modules may be implemented in software and stored in the memory **604** of the base station **600** shown in FIG. **6** with the modules controlling operation of small base station **600** to implement the functions corresponding to the modules when the modules are executed by a processor, e.g., processor **602**. In some such embodiments, the assembly of modules **700** is included in routines **611** of memory **604** of base station **600** of FIG. **6**. In still other embodiments, various modules are implemented as a combination of hardware and software, e.g., with another circuit external to the processor providing input to the processor **602** which then under software control operates to perform a portion of a module's function.

While shown in the FIG. **6** embodiment as a single processor, e.g., computer, it should be appreciated that the processor **602** may be implemented as one or more processors, e.g., computers. When implemented in software the modules include code, which when executed by the processor, configure the processor, e.g., computer, **602** to implement the function corresponding to the module. In some embodiments, processor **602** is configured to implement each of the modules of the assembly of modules **700**. In embodiments where the assembly of modules **700** is stored in the memory **604**, the memory **604** is a computer program product comprising a computer readable medium, e.g., a non-transitory computer readable medium, comprising code, e.g., individual code for each module, for causing at least one computer, e.g., processor **602**, to implement the functions to which the modules correspond.

Completely hardware based or completely software based modules may be used. However, it should be appreciated that any combination of software and hardware (e.g., circuit implemented) modules may be used to implement the functions. As should be appreciated, the modules illustrated in FIG. **7** control and/or configure the base station **600** or elements therein such as the processor **602**, to perform the functions of the corresponding steps illustrated and/or described in the method of flowchart **500** of FIG. **5**.

Assembly of modules **700** includes a module **704** configured to receive information indicating communications resources that are dedicated for use in transmitting pilot signals to or receive pilot signals from user equipment (UE) devices, e.g., from a macro base station, a module **705** configured to determine the communications resources dedicated for use in transmitting pilot signals to or receive pilot signals from UE devices, e.g., based on the received information or the previously stored information indicating the resources dedicated for use in transmitting or receiving pilot signals, a module **706** configured to receive information indicating whether base stations are to transmit pilot signals using the dedicated communications resources or UE devices are to transmit pilot signals using the dedicated communications resources, and a module **708** configured to determine whether the base stations or UE devices are to transmit pilot signals using the dedicated communications resources, e.g., based on the received information. In various embodiments the determination module **708** is configured to perform/implement the functions discussed in the corresponding step **508** of flowchart **500**. Thus in various embodiments the module **708** is configured to determine whether a mode indicator indicating whether base stations or UE devices are to transmit pilot signals using the dedicated communications resources is received and perform one or more other determinations discussed in step **910** and/or the sub-steps therein. In some embodiments when a mode indicator is not received the determination module **708** is configured to determine that the base station **600** is to operate in a default mode. In some embodiments in the default mode the base station **600** considers that base stations are to transmit pilot signals using the dedicated communications resources. In some other embodiments in the default mode the base station **600** considers that the UE devices are to transmit pilot signals using the dedicated communications.

In various embodiments the assembly of modules **700** further includes a module **726** configured to monitor communications resources dedicated for use in transmitting pilot signals for pilot signals transmitted by UE devices, a module **736** configured to monitor the communications resources dedicated for transmitting pilot signals to identify resources which are unused, and a module **738** configured to monitor for signals from UE devices. The assembly of modules **700** in some embodiments further includes a module **728** configured to receive a pilot signal, e.g., from a UE device, a module **730** configured to perform measurements to measure the received signal strength of the received pilot signal, a module **732** configured to estimate a signal to noise ratio (SNR) to the UE device from which the pilot signal was received, and a module **734** configured to report the measured pilot signal strength and the estimated SNR along with device identification information to one of a base station serving the UE from which the pilot signal was received or to a control node, e.g., radio network controller. In some embodiments the module **734** for reporting includes a module **752** configured to generate a report including the measured pilot signal strength, estimated SNR and UE device identification information, and a module **754** configured to send, e.g., transmit, the generated report to one of a base station serving the UE from which the pilot signal was received or to the control node, e.g., radio network controller.

In various embodiments the assembly of modules **700** further includes a module **740** configured to select one or more identified unused communications resources from the communications resources dedicated for use in transmitting pilot signals, and a module **742** configured to transmit pilot signals and identification information on communications resources included in the communications resources dedicated for use in transmitting pilot signals when it is determined that the base stations are to transmit pilot signals using the dedicated resources. In some embodiments the module **742** includes a module **744** configured to transmit pilot signals and identification information on the selected identified unused communications resources as part controlling transmission of the pilot signals on the communications resources included in the dedicated communications resources. In some embodiments the module **740** is configured to measure energy on the communications resources dedicated for pilot transmissions to identify the unused dedicated resources. In some embodiments the module **740** identifies communications resources on which least amount of energy or energy below a predetermined threshold is detected as the unused communications resources. In some embodiments the module **742** is configured to transmit the pilot signals on the selected identified resources periodically.

In some embodiments the assembly of modules **700** further includes a module **746** configured to control the base station **600** to cease transmitting pilot signals when a signal from at least one UE device is not detected for a predetermined period of time during the monitoring operation. In some embodiments the assembly of modules **700** further includes a module **748** configured to detect/receive a signal from a UE device, and a module **750** configured to control the base station **600** to resume the pilot signal transmission operation following the detection of the signal from the UE device.

The modules shown in dashed lines boxes are optional, and thus one or more of these modules may be present in some embodiments while not in others. The dashed boxes indicate that although these modules are included in the assembly of modules **700** in various embodiments, the processor **602** may execute such an optional module in embodiments where the step to which these modules correspond, is performed. In some embodiments, one or more modules shown in FIG. **7** which are included within another module may be implemented as an independent module or modules.

FIG. **8** illustrates an exemplary measurement report **800**, communicated, e.g., from a small base station or a UE device that receives a pilot signal and performs measurements, in accordance with an exemplary embodiment. In some embodiments the measurement report **800** is generated by a base station, e.g., a femtocell or picocell, that receives pilot signals from one or more UE devices on the communications resources dedicated for pilot signal transmissions. In some embodiments the measurement report **800** is generated by a UE device that receives pilot signals from one or more small base stations transmitted on the communications resources dedicated for pilot signal transmissions.

As shown, the exemplary measurement report **800** includes a plurality of information fields including a message type ID field **802**, a source ID field **804**, a destination device ID field **806**, a device identification information field **808**, a signal to noise ratio (SNR) information field **810**, and a measured received pilot signal strength field **812**.

The message type ID field **802** includes an identifier that identifies a type of message to which the measurement report message **800** relates, for example, the information in field **802** identifies that the information in measurement report message **800** relates to pilot signal measurements. The source ID **804** includes an identifier corresponding to the device which is performing the measurements and transmitting the measurement report message **800**, e.g., ID of a small base station or UE device that performs the measurements and transmits message **800**.

The destination device ID field **806** includes identifier corresponding to the destination device to which the measurement report message **800** is sent. In accordance with one aspect of some embodiments the measurement report may be sent by a small base station to a base station serving the UE device from which a pilot signal is received or to a central control node such as a radio network controller (RNC). In accordance with one aspect of some embodiments the measurement report may be sent by a UE device to a small base station from which a pilot signal is received or to a central control node such as a radio network controller (RNC) or macro base station. Thus the information field **806** may include an identifier corresponding to a base station and/or an RNC.

The information field **808** includes identification information corresponding to the device, e.g., a UE device or small base station, the femto base station, which transmitted the pilot signal on which the signal measurements were performed. The SNR information field **810** includes the estimated SNR to the device from which the pilot signal was received. The signal strength information field **812** includes the measured received signal strength of the received pilot signal as measured by the device transmitting the measurement report message **800**.

FIG. **9** is a flowchart **900** showing the steps of an exemplary method of operating a user equipment (UE) device, in accordance with an exemplary embodiment. In some embodiments the UE device implementing the method of flowchart **900** is any one of the active UEs shown in FIG. **1**. For the purposes of discussion consider that UE **1 102** implements the method of flowchart **900**.

Operation starts in step **902**. In step **902** the UE **1 102** is powered on and initialized. In some embodiments the flow chart **900** is implemented by the UE only when it is in active state, i.e. when it is communication with a base station. Operation proceeds from start step **902** to step **904**. In step **904** receives information, e.g., in a wireless signal, indicating communications resources that are dedicated for use in transmitting pilot signals to or receive pilot signals from base stations, e.g., from a macro base station such as base station **124**. In some embodiments step **904** may not be performed and the information indicating communications resources dedicated for use in transmitting pilot signals to or receive pilot signals from base stations may be pre-stored in the UE device implementing the method of flowchart **900**.

Operation proceeds from step **904** to step **906**. In step **906** the UE device determines the communications resources dedicated for use in transmitting pilot signals to or receiving pilot signals from the base stations. The determination is made, e.g., based on the received information or the previously stored information indicating the resources dedicated for use in transmitting or receiving pilot signals as discussed above.

Operation proceeds from step **906** to step **908**. In step **908** the UE device receives information indicating whether base stations are to transmit pilot signals using the dedicated communications resources or UE devices are to transmit pilot signals using the dedicated communications resources. The information is received e.g., from a macro base station or a central control node in some embodiments. In some embodiments the received information in step **908** includes a mode indicator which indicates to the UE device **1 102** whether the base stations or the UE devices are to transmit pilot signals using the dedicated communications resources. In some embodiments the mode indicator indicates that the UE device **1 102** is to operate in a mode in which the base stations are to transmit pilot signals using the dedicated communications resources. Step **908** is illustrated in a dashed box as it is optional and thus in some embodiments step **908** is not performed and information indicating whether the base stations or the UE devices are to transmit pilot signals using the dedicated communications resources is not received. In such embodiments the UE device **1 102** operates in a default mode which can be pre-configured in some embodiments. For example, in some embodiments in the default mode the base stations are to transmit pilot signals using the dedicated communications resources.

Operation proceeds from step **908** to step **910**. In step **910** the UE device determines, e.g., based on the received information indicating which device (e.g., base stations or UEs) is to transmit pilot signals, whether the UE device is to transmit pilot signals using the dedicated communications resources or the base stations are to transmit pilot signals using the dedicated communications resources.

In various embodiments, as part of determining step **910**, one or more of steps **912**, **914**, **916**, **918**, **920** and **922** are performed. In sub-step **912** the UE device determines if a mode indicator has been received, e.g., as part of the received information. If it is determined that a mode indicator has not been received, the operation proceeds to sub-step **916**. If in step **912** it determined that a mode indicator has been received, the operation proceeds to sub-step **914** where it determined if the received mode indicator indicates a first mode of operation. If in sub-step **914** it is determined that the mode indicator does not indicate the first mode, operation proceeds from sub-step **914** to sub-step **916** where the UE device **1 102** operates in accordance with a default mode. Operation proceeds from sub-step **916** to sub-step **918** where the UE device determines if the default mode is set to a mode in which base stations are to transmit pilot signals using the dedicated communications resources. If it determined that the default mode is set to a mode in which base stations are to transmit pilot signals the operation proceeds to step **928** via connecting node D **924**, otherwise the operation proceeds to steps **938** and **940** via connecting node E **926**.

Referring again to step **914**, if in step **914** it is determined if the received mode indicator indicates a first mode, the operation proceeds from sub-step **914** to sub-step **920** where the UE device operates in accordance with the first mode. Operation proceeds from sub-step **920** to sub-step **922** where the UE device determines if the first mode is set to a mode in which base stations are to transmit pilot signals. If in step **922** it is determined that the first mode is set to a mode in which base stations are to transmit pilot signals the operation proceeds from step **922** to step **928** via connecting node D **924**, otherwise it is considered that the first mode is set to a mode in which UE devices are to transmit pilot signals and the operation proceeds to steps **938** and **940** via connecting node E **926**. In various embodiments the default mode and the first mode are different and can be set/controlled by, e.g., the macro base station that allocates the dedicated communications resources for pilot transmissions, or by the control entity, e.g., control node **130**.

Thus, depending on whether the base stations or the UE devices are to transmit pilot signals, the operation proceeds along one of two possible processing paths as illustrated.

Consider processing path that continues through node D **924**. As discussed above, before reaching this processing point at connecting node D **924** it has been determined that the base stations are to transmit pilot signals. In step **928** the UE device monitors the communications resources, dedicated for use in transmitting pilot signals, for pilot signals transmitted by base stations, e.g., femtocells or picocells. Thus in step **928** the UE device begins monitoring for pilot signal transmissions from base stations on the dedicated communications resources.

Operation proceeds from step **928** to step **930**. In step **930** the UE device receives a pilot signal from a base station, e.g., a femtocell or picocell. In various embodiments the transmitted pilot signals include at least one pilot and identification information corresponding to the transmitting device, e.g., ID of transmitting base station or UE device. Operation proceeds from step **930** to step **932**. In accordance with one aspect of some embodiments, in step **932** the UE device performs a measurement to measure the received pilot signal strength of the pilot signal received from the base station. Operation proceeds from step **932** to step **934**. In step **934** the UE device estimates a signal to noise ratio (SNR) to the base station from which the pilot signal was received. Operation proceeds from step **934** to step **936**. In step **936** the UE device generates a measurement report including the measured received pilot signal strength and the estimated SNR along with identification information of the base station from which the pilot signal is received and sends the generated report to one of a base station serving the UE device performing the measurements or to a control node, e.g., radio network controller. In some embodiments a macro base station **124** that allocated the resources dedicated for pilot transmissions may act as a control node. Operation proceeds from step **936** back to step **904** via connecting node F **960**.

Referring now to steps **938** and **940** long the other processing path that continues through node E **926**. In step **938** the UE device monitors for signals from base stations, e.g., femtocells or picocells, e.g., to determine if one or more small base stations are present. The UE device may monitor for discovery signals, pilots, downlink data transmissions and/or synchronization signals such as PSS (primary synchronization signal) or SSS (secondary synchronization signal) from small base stations. UE device may monitor non-cellular signals transmitted by small base stations e.g. peer to peer communication signals. If a signal from one or more small base stations is detected during the monitoring, this indicates that the one or more small base stations from which the signal(s) are detected are present, e.g., in the vicinity of the UE device. Operation proceeds from step **938** to steps **944** and **9948**.

In step **940**, following a determination that the UE devices are to transmit pilot signals using the dedicated communications resources, the UE device monitors the communications resources dedicated for transmitting pilot signals to identify resources which are unused. In various embodiments the UE device monitors the resources to detect/measure energy on the resources. In some embodiments the resources on which least amount of energy or energy below a predetermined threshold is detected are considered unused. Operation proceeds from step **940** to step **942**.

In step **942** the UE device selects one or more identified unused communications resource(s) from the communications resources dedicated for use in transmitting pilot signals. In some embodiments the UE device selects unused communication resource(s) autonomously. In some embodiments the resources selected by the UE device may depend on the identity of the UE device and/or identity of base station serving UE device. Operation proceeds from step **942** to step **944**. In step **944** the UE device transmit pilot signals and identification information on communications resources included in the communications resources dedicated for use in transmitting pilot signals. In various embodiments step **944** includes step **946** where the UE device transmits pilot signals and identification information on the selected identified unused communications resources as part of transmitting the pilot signals on the communications resource(s) included in the dedicated communications resources. In some embodiments the identification information may include identity of the UE device and/or identity of base station serving the UE device. It should be noted that the UE device may transmit in the dedicated resources allocated by the macro base station during the time period when it is served by a small base station. In such embodiments the timing used by the UE device to transmit pilot signals may be derived from the signals it receives from macro base station. The UE device may use other timing for communication with the serving base station. In some embodiments, in step **926**, the UE device transmits pilot signals at a predetermined power. In some embodiments step **944** is performed on a periodic basis. In various embodiments the transmitted pilot signals include at least one pilot and identification information corresponding to the transmitting UE device. Operation proceeds from step **944** to step **948**.

In step **948** the UE device ceases to transmit pilot signals on the dedicated resources when it fails to detect a signal from at least one base station e.g., small base station, for a predetermined period of time during the monitoring operation, e.g., the monitoring illustrated in step **938**. Thus in accordance with one feature, in some embodiments the UE device stops transmitting pilot signals and identification information when it determines that small base stations are, e.g., not in the vicinity as indicated by lack of detected signals from at least small one base station for a predetermined time during the monitoring operation. However it should be appreciated that when signals from one or more small base stations are detected during the monitoring, the UE device continues to transmit the pilot signals, e.g., periodically.

Consider for example that the UE device ceased to transmit pilot signals in step **948**. Operation proceeds from step **948** to step **950** which is an optional step. In step **950** the UE device detects/receives a signal from a small base station. Operation proceeds from step **950** to step **952**. Following the detection of a signal from the small base station, the UE device again resumes the pilot signal transmission operation in step **952**, e.g., the transmission operation as discussed in detail in step **944** and **946**. Operation proceeds from step **952** back to step **904** via connecting node F **960** and the operation may continue in this manner over time.

FIG. **10** is a drawing of an exemplary user equipment (UE) device **1000**, e.g., a mobile wireless terminal, in accordance with various embodiments. Exemplary UE device **1000** can be used as any one of the UE devices **102**, **104**, . . . **110**, shown in FIG. **1**. Exemplary UE device **1000** can, and sometimes does, transmit pilot signals and identification information on the communications resources allocated for pilot signal transmissions. The UE device **1000** may, and sometimes does, implement a method in accordance with flowchart **900**.

The UE device **1000** includes a processor **1002** and memory **1004** coupled together via a bus **1009** over which the various elements (**1002**, **1004**) may interchange data and information. The UE device **1000** further includes an input module **1006** and an output module **1008** which may be coupled to processor **1002** as shown. However, in some embodiments, the input module **1006** and output module **1008** are located internal to the processor **1002**. Input module **1006** can receive input signals. Input module **1006** includes a wireless receiver module **1020** for receiving input including over wireless communications links. Input module **1006** also includes a wired and/or optical input receiver module **1022** for receiving input over a wired and/or optical link. Output module **1008** includes a wireless transmitter module **1026** for transmitting output signals over wireless communications links. Output module **1008** also includes a wired and/or optical output transmitter module **1028** for transmitting output signals over a wired and/or optical link. Memory **1004** includes routines **1011**, and data/information **1013**.

The UE device **1000** further includes wireless communications receive antenna **1024** coupled to wireless receiver module **1020** and wireless communications transmit antenna **1030** coupled to wireless transmitter module **1026**. In some embodiments, the same antenna is used for both input and output wireless communications signaling.

In various embodiments, processor **1002** is configured to control the UE device **1000** to receive, e.g., from a macro base station such as base station **124**, information indicating communications resources that are dedicated for use in transmitting pilot signals to or receive pilot signals from base stations, and determine the communications resources dedicated for use in transmitting pilot signals to or receive pilot signals from base stations. The information in some embodiments is received in a wireless signal. In some embodiments the processor **1002** is configured to make the determination, e.g., based on the received information or the previously stored information indicating the communications resources dedicated for use in transmitting or receiving pilot signals.

In various embodiments the processor **1002** is further configured to control the UE device to receive information indicating whether base stations are to transmit pilot signals using the dedicated communications resources or UE devices are to transmit pilot signals using the dedicated communications resources, and determine whether the UE devices are to transmit pilot signals using the dedicated communications resources or the base stations are to transmit pilot signals using the dedicated communications resources. The information is received e.g., from a macro base station or a central control node in some embodiments. In some embodiments the received information includes a mode indicator which indicates whether the base stations or the UE devices are to transmit pilot signals using the dedicated communications resources. In some embodiments the processor **1002** is configured to, as part of being configured to determine whether the base stations or UE devices are to transmit pilot signals, determine whether a mode indicator has been received and control the base station to operate in accordance with the indicated mode. In some embodiments when information indicating whether the base stations or UE devices are to transmit pilot signals and/or a mode indicator is not received, the processor **1002** is configured to determine that the UE device is to operate in a default mode. Depending on the embodiment, a default mode may be set to a mode in which either the base stations transmit pilot signals using the dedicated communications resources or the UE devices transmit pilot signals using the dedicated communications resources.

In various embodiments if it is determined that the base stations are to transmit pilot signals using the dedicated resources, the processor **1002** is further configured to monitor the communications resources dedicated for use in transmitting pilot signals for pilot signals transmitted by base stations, control the UE device to receive (e.g., via input module **1006**) a pilot signal from a base station, perform a measurement to measure the received signal strength of the pilot signal received from the base station, generate an estimate of a signal to noise ratio (SNR) to the base station from which the pilot signal was received, and generate a measurement report including the measured pilot signal strength and the estimated SNR along with identification information of the base station from which the pilot signal is received. In various embodiments the processor **1002** is further configured to control the UE device to send, e.g., transmit via the output module **1008**, the generated report to one of a base station serving the UE or to a control node, e.g., radio network controller.

In various embodiments when it is determined that the UE devices are to transmit pilot signals using the dedicated resources, the processor **1002** is further configured to monitor for signals from base stations, e.g., femtocells or picocells, monitor the communications resources dedicated for transmitting pilot signals to identify resources which are unused, and select one or more identified unused communications resources from the communications resources dedicated for use in transmitting pilot signals, and control the UE device to transmit pilot signals and identification information on communications resources included in the communications resources dedicated for use in transmitting pilot signals. In various embodiments the processor **1002** is configured to control the UE device to transmit pilot signals and identification information on the selected identified unused communications resources as part of being configured to control transmission of pilot signals on the communications resources included in the dedicated communications resources. In some embodiments the processor **1002** is configured to control the UE device to transmit pilot signals on a periodic basis.

In some embodiments the processor **1002** is configured to measure energy on the communications resources as part of being configured to identify unused communications resources and identify the resources on which least amount of energy or energy below a predetermined threshold is detected as the unused communications resources. In various embodiments the transmitted pilot signals include at least one pilot and identification information corresponding to the transmitting UE device.

In some embodiments the processor **1002** is configured to control the UE device to cease to transmit pilot signals when a signal from at least one small base station is not detected for a predetermined period of time during the monitoring operation. In some embodiments the processor **1002** is further configured to resume the pilot signal transmission when a signal from a small base station is detected. Thus in some embodiments the processor **1002** is configured to control the UE device to: detect/receive a signal from a small base station and resume transmission of pilot signals.

FIG. **11** is an assembly of modules **1100** which can, and in some embodiments is, used in the exemplary UE device **1000** illustrated in FIG. **10**. The modules in the assembly **1100** can be implemented in hardware within the processor **1002** of FIG. **10**, e.g., as individual circuits. The modules in the assembly **1100** can, and in some embodiments are, implemented fully in hardware within the processor **1002**, e.g., as individual circuits. In other embodiments some of the modules are implemented, e.g., as circuits, within the processor **1002** with other modules being implemented, e.g., as circuits, external to and coupled to the processor. As should be appreciated the level of integration of modules on the processor and/or with some modules being external to the processor may be one of design choice. In some but not necessarily all embodiments some of the modules discussed below, e.g., modules **1106**, **1110**, **1128**, **1138**, **1140**, **1132**, and **1134**, are implemented in the processor **1002** with the other modules, e.g., modules **1104**, **1108**, **1144** etc., being implemented in the processor and/or external to the processor **1002**.

Alternatively, rather than being implemented as circuits, all or some of the modules may be implemented in software and stored in the memory **1004** of the UE device **1000** shown in FIG. **10** with the modules controlling operation of the UE device **1000** to implement the functions corresponding to the modules when the modules are executed by a processor, e.g., processor **1002**. In some such embodiments, the assembly of modules **1100** is included in routines **1011** of memory **1004** of the UE device **1000** of FIG. **10**. In still other embodiments, various modules are implemented as a combination of hardware and software, e.g., with another circuit external to the processor providing input to the processor **1002** which then under software control operates to perform a portion of a module's function.

While shown in the FIG. **10** embodiment as a single processor, e.g., computer, it should be appreciated that the processor **1002** may be implemented as one or more processors, e.g., computers. When implemented in software the modules include code, which when executed by the processor, configure the processor, e.g., computer, **1002** to implement the function corresponding to the module. In some embodiments, processor **1002** is configured to implement each of the modules of the assembly of modules **1100**. In embodiments where the assembly of modules **1100** is stored in the memory **1004**, the memory **1004** is a computer program product comprising a computer readable medium, e.g., a non-transitory computer readable medium, comprising code, e.g., individual code for each module, for causing at least one computer, e.g., processor **1002**, to implement the functions to which the modules correspond.

Completely hardware based or completely software based modules may be used. However, it should be appreciated that any combination of software and hardware (e.g., circuit implemented) modules may be used to implement the functions. As should be appreciated, the modules illustrated in FIG. **11** control and/or configure the UE device **1000** or elements therein such as the processor **1002**, to perform the functions of the corresponding steps illustrated and/or described in the method of flowchart **900** of FIG. **9**.

Assembly of modules **1100** includes a module **1104** configured to receive information indicating communications resources that are dedicated for use in transmitting pilot signals to or receive pilot signals from base stations, e.g., small base stations, a module **1106** configured to determine the communications resources dedicated for use in transmitting pilot signals to or receive pilot signals from base stations, e.g., based on the received information or the previously stored information indicating the resources dedicated for use in transmitting or receiving pilot signals, a module **1108** configured to receive information indicating whether base stations are to transmit pilot signals using the dedicated communications resources or UE devices are to transmit pilot signals using the dedicated communications resources, and a module **1110** configured to determine whether the base stations or UE devices are to transmit pilot signals using the dedicated communications resources. In some embodiments the determination module **1110** performs the determination, e.g., based on the received information indicating whether base stations or UE devices are to transmit pilot signals using the dedicated communications resources. In various embodiments the determination module **1110** is configured to perform/implement the functions discussed in the corresponding step **910** of flowchart **900**. Thus in various embodiments the module **1110** is configured to determine whether a mode indicator indicating whether base stations or UE devices are to transmit pilot signals using the dedicated communications resources is received and perform one or more other determinations discussed in step **910** and/or the sub-steps therein. In some embodiments when a mode indicator is not received the determination module **1110** is configured to determine that the UE device **1000** is to operate in a default mode.

In various embodiments the assembly of modules **1100** further includes a module **1128** configured to monitor communications resources, dedicated for use in transmitting pilot signals, for pilot signals transmitted by base stations, a module **1138** configured to monitor for signals from base stations, and a module **1140** configured to monitor the communications resources dedicated for transmitting pilot signals to identify resources which are unused.

The assembly of modules **1100** in some embodiments further includes a module **1130** configured to receive a pilot signal from at least one base station, e.g., femtocell or picocell, a module **1132** configured to perform measurements to measure the received signal strength of the received pilot signal, a module **1134** configured to estimate a signal to noise ratio (SNR) to the base station from which the pilot signal was received, and a module **1136** configured to report the measured pilot signal strength and the estimated SNR along with identification information of the base station from which the pilot signal was received to one of a base station or to a control node, e.g., radio network controller. In some embodiments the module **1136** for reporting includes a module **1154** configured to generate a report including the measured pilot signal strength, the estimated SNR and base station identification information, and a module **1156** configured to transmit the generated report to one of a base station serving the UE or to the control node, e.g., radio network controller.

In various embodiments the assembly of modules **1100** further includes a module **1142** configured to select one or more identified unused communications resources for transmitting pilot signals from the communications resources dedicated for use in transmitting pilot signals, and a module **1144** configured to transmit pilot signals and identification information on communications resources included in the communications resources dedicated for use in transmitting pilot signals when it is determined that the UE devices are to transmit pilot signals using the dedicated resources. In some embodiments the module **1142** is configured to measure energy on the communications resources dedicated for pilot transmissions to identify the unused dedicated resources. In some embodiments the module **1142** identifies communications resources on which least amount of energy or energy below a predetermined threshold is detected as the unused communications resources. In some embodiments the module **1144** includes a module **1146** configured to control the UE device to transmit, e.g., via the output module **1008**, pilot signals and identification information on the selected identified unused communications resources as part of controlling the UE device to transmit the pilot signals on the communications resources included in the dedicated communications resources.

In some embodiments the assembly of modules **1100** further includes a module **1148** configured to control the UE device to cease transmitting pilot signals when a signal from at least one small base station is not detected for a predetermined period of time during the monitoring operation. In some embodiments the assembly of modules **1100** further includes a module **1150** configured to detect/receive a signal from a small base station, and a module **1152** configured to control the UE device to resume the pilot signal transmission operation following the detection of the signal from a small base station, e.g., one of a femto base station or pico base station.

The modules shown in dashed lines boxes are optional, and thus one or more of these modules may be present in some embodiments while not in others. The dashed boxes indicate that although these modules are included in the assembly of modules **1100** in various embodiments, the processor **1002** may execute such an optional module in embodiments where the step to which these modules correspond, is performed. In some embodiments, one or more modules shown in FIG. **11** which are included within another module may be implemented as an independent module or modules.

Various features may be used in a wide range of systems and/or methods. In accordance with one aspect, an exemplary method in accordance with some embodiments, includes one, more or all of the following features and/or steps.

In at least one embodiment a macro cell **124** (e.g., an eNodeB a.k.a. eNB) configures, e.g, allocates, a group of periodic time and communications resources (sometimes referred to herein as handover resources) to be used for pilot transmissions intended to facilitate handover related signal measurements. The macro cell **124** configures, e.g., allocates the resources for their intended purpose, in one more or all carriers, e.g., frequencies, in which a small base station (also referred to as small cell) is deployed within the coverage area of the macro cell **124**. The resources and periodicity can, and in some embodiments do, differ with the carrier and/or number of small cells or UE devices **102**, **106**, **110** present in the area in which the resources are being allocated.

The macro base station **124** then configures either small cells **112**, **116** or active UEs **102**, **106**, **110** in the macro base station's coverage area to transmit on the handover resources, e.g., pilot signals and related information. The selection of either the small cells or active UEs should transmit is based, in some embodiments, on the density of the small cells and the density of the active UEs in the macro cell **124** where the active UEs and the small cells are within the coverage area **161** of the macro cell. In some embodiments the macro base station **124** configures the active UEs **102**, **106**, **110** to transmit pilot signals using the handover resources if the number of UEs is smaller than the number small cells. In this state, the small cells **112**, **116** are configured to receive the signals transmitted by the active UEs using the handover resources. This communication may be described as uplink communication as should be appreciated from the fact the UEs **102**, **106**, **110** are transmitting the pilot signals. Alternatively, the macro base station **124** configures the small cells **112**, **116** to transmit pilot signals in the handover resources if the number of active UEs **102**, **106**, **110** is greater than the number of the small cells **112**, **116**. The configuration of the small cells **112**, **116** and/or UEs **102**, **106**, **110** can be performed by the macro base station **124** transmitting, e.g., broadcasting or otherwise communicating, configuration information to the UEs **102**, **106**, **110** and/or small cells **112**, **116**.

When the small base stations **112**, **116** are configured to transmit pilots, the active UEs **102**, **106**, **110** are configured to receive the signals transmitted by the small cells **112**, **116** using the handover resources. This communication may be described as downlink communication since it involves transmission performed by one or more small base stations **112**, **116**.

In some embodiments the configuration of whether small base stations **112**, **116** or UEs **102**. **106**, **110** are to transmit pilot signals on resources allocated by the macro base station **124** can change dynamically in time and space. For example, a first macro base station **124** can configure small cells associated with the first macro base station **124** as transmitters and a second macro base station, e.g., located adjacent the first macro base station **124** in another macro cell **171** can configure UEs **102**, **106**, **110** associated with the second macro base station as transmitters of pilot signals at the same time UEs **102**, **106**, **110** in the adjacent cell **161** are configured to be receivers of pilot signals. Furthermore, the first macro base station **124** may initially configure small cells associated with the first macro base station **124** to transmit using the handover resources and UEs associated with the first macro base station **124** to receive using the handover resources and later, e.g., at some later point in time, the first macro base station **124** may configure the UEs **102**, **106**, **110** in its cell **161** to transmit using the handover resources and the small cells **112**, **116** to receive, e.g., the transmitted pilot signals and corresponding device identification information, using the handover resources. In one embodiment, the macro base station **124** changes the configuration of whether small cells **112**, **116** or UEs **102**, **106**, **110** should transmit pilots based on the number of small cells associated with, e.g., in the coverage area of, the first macro base station **124** and the number of active UEs **102**, **106**, **110** associated with, e.g., in the coverage area **161**, of the first macro base station **124**.

In some embodiments when handover resources which are dedicated for use by small cells **112**, **116** or UEs **102**, **106**, **110** are allocated for uplink communication during which the UEs **102**, **106**, **110** transmit e.g., pilot signal, via the handover resources and the small cells **112**, **116** receive via the handover resources. In at least some such embodiments when handover resources are dedicated on the uplink the small cells **112**, **116** do not transmit pilots and no pilot transmission resources are made available to the small cells **112**, **116** for transmission of pilots on the downlink.

In at least some embodiments when handover resources are allocated on the downlink, the small cells **112**, **116** transmit, e.g., pilots, via the handover resources and the UEs **102**, **106**, **110** receive via the handover resources but do not transmit pilots. In some embodiments, the handover resources are allocated in the frequency band in which the small cells **112**, **116** transmit (downlink band) and in some other embodiments the handover resources are allocated in the frequency band in which the UEs **102**, **106**, **110** transmit (uplink band).

In various embodiments the configured transmitters, e.g., the UEs **102**, **110** or the small base stations **112**, **120**, select one of the handover resources autonomously and transmit a wideband signal periodically in the selected resource. The devices transmitting the pilots transmit wide band pilot signals, e.g., at predetermined power level, along with information indicating the transmitting devices identity. The wideband pilot may include a signal transmitted on each of a plurality of different tones, e.g. during a single or multiple symbol transmission time periods. In some embodiments, an S-TMSI is used as the identifier in case when the UEs **106**, **110** are to transmit pilots, and cell ID is used as an identifier in case when small cells **112**, **120** are to transmit pilots. A transmitter, e.g., transmitting device, can, and in some embodiments does, make measurements of one or more of the handover resources and, based on the measurements, choose the resource on which it received the least amount of energy to use for its pilot signal transmissions. In this way the risk of collusions can be reduced or minimized as compared to the case where devices, e.g., UEs **102**, **110** or small cells **112**, **120**, randomly select from the available pilot signal transmission resources to transmit there pilots and corresponding identification information.

In various embodiments the devices e.g., UEs **102**, **110** or small cells **112**, **120**, transmitting with a macro cell **161**, use a timing derived from a common source. For example, downlink timing received from the macro base station **124** or uplink timing used to transmit to the macro base station **124**.

In some but not all embodiments to avoid unnecessary interference to other pilot transmissions that may share the same handover resources as those being used by the transmitting device, the transmitting device transmits on the handover resource only when there are receivers known to nearby, e.g., within communication range, of the transmitting device. For example in some embodiments if the transmitters are small cells **112**, **116**, they monitor for active UEs **102**, **106**, **110** nearby by receiving signals and checking the signals to determine they are UE specific signals, e.g., signals which can be decoded and relate to the presence or indicate the presence of an active UE. Signals which are monitored for to detect UE presence include, in some embodiments specific signals such as, e.g., SRS, PRACH, PUCCH, etc. which are transmitted by active UEs **102**, **106**, **110** and which can be detected by a small base station **112**, **116** in the presence of a UE **102**, **106**, **110**.

In some but not all embodiments, if the transmitters of pilot signals are active UEs **102**, **106**, **110**, the active UEs **102**, **106**, **110** determine that a small cell **112**, **116** is nearby by monitoring for and attempting to detect signals from the small cell **112**, **116**. When such signals from small cells are detected, the UE **102**, **106**, **10** will transmit pilots but not when a small cell **112**, **116** is not detected. The UE **102**, **106**, **110** may detect the presence of a small cell by decoding discovery signals transmitted by the small cells **112**, **116**. The signals which can, and sometimes are, detected and decoded to determine the presence of a small cell include, e.g., PSS/SSS or LTED like discovery signals.

In various embodiments the devices monitoring to receive pilots, e.g., either the small cells **112**, **116** or the active UEs **106**, **110**, depending on the configuration being implemented, measure the pilot signals transmitted using the handover resources and report the handover measurements (e.g., RSSI) to the macro base station **124** or to a centralized entity such as control node **130**, other than the source macro base station **124**, to which the active UE **106**, **110**. In some embodiments the control node **130** is a radio network controller which has control over handover decisions.

Depending on the embodiment, the macro base station **124** or the centralized entity **130** makes a handover decision based on the reported handover measurements. The centralized entity **130** making the decision communicates the decision to the corresponding macro base station **124** (when the base station is not the decision making node). The handover information is also communicated to the macro base station **124** or small base station **112**, **116** to which the handover is being made via the backhaul network. The corresponding UE to which a handover decision relates is notified when a handover is to occur via downlink signals transmitted by the serving base station **124**, **112**, or **116** at the time of the handover. The entity making a handover decision, e.g., macro base station **124** or the centralized **130** entity may, and in some embodiments does, base its decision not only on RSSI measurements but also on one or more other factors such as interference caused to other small cells **112**, **116** by turning on a new small cell, the backhaul capacity of the small cell, type of quality of service (QoS) supported by the small cell and required by UE etc.

The techniques of various embodiments may be implemented using software, hardware and/or a combination of software and hardware. Various embodiments are directed to apparatus, e.g., mobile nodes such as mobile wireless terminals, base stations, communications system. Various embodiments are also directed to methods, e.g., method of controlling and/or operating a communications device, e.g., wireless terminals (UEs), base stations, control nodes and/or communications systems. Various embodiments are also directed to non-transitory machine, e.g., computer, readable medium, e.g., ROM, RAM, CDs, hard discs, etc., which include machine readable instructions for controlling a machine to implement one or more steps of a method.

It is understood that the specific order or hierarchy of steps in the processes disclosed is an example of exemplary approaches. Based upon design preferences, it is understood that the specific order or hierarchy of steps in the processes may be rearranged while remaining within the scope of the present disclosure. The accompanying method claims present elements of the various steps in a sample order, and are not meant to be limited to the specific order or hierarchy presented.

In various embodiments devices and nodes described herein are implemented using one or more modules to perform the steps corresponding to one or more methods, for example, signal generation, transmitting, processing, and/or receiving steps. Thus, in some embodiments various features are implemented using modules. Such modules may be implemented using software, hardware or a combination of software and hardware. Many of the above described methods or method steps can be implemented using machine executable instructions, such as software, included in a machine readable medium such as a memory device, e.g., RAM, floppy disk, etc. to control a machine, e.g., general purpose computer with or without additional hardware, to implement all or portions of the above described methods, e.g., in one or more nodes. Accordingly, among other things, various embodiments are directed to a machine-readable medium e.g., a non-transitory computer readable medium, including machine executable instructions for causing a machine, e.g., processor and associated hardware, to perform one or more of the steps of the above-described method(s). Some embodiments are directed to a device including a processor configured to implement one, multiple or all of the steps of one or more methods of the invention.

In some embodiments, the processor or processors, e.g., CPUs, of one or more devices, e.g., communications devices such as wireless terminals (UEs), and/or access nodes, are configured to perform the steps of the methods described as being performed by the devices. The configuration of the processor may be achieved by using one or more modules, e.g., software modules, to control processor configuration and/or by including hardware in the processor, e.g., hardware modules, to perform the recited steps and/or control processor configuration. Accordingly, some but not all embodiments are directed to a communications device, e.g., user equipment, with a processor which includes a module corresponding to each of the steps of the various described methods performed by the device in which the processor is included. In some but not all embodiments a communications device includes a module corresponding to each of the steps of the various described methods performed by the device in which the processor is included. The modules may be implemented purely in hardware, e.g., as circuits, or may be implemented using software and/or hardware or a combination of software and hardware. In embodiments where modules are implemented as circuits, the apparatus may, and in some embodiments does, include a separate individual circuit for performing the function corresponding to each individual module. Thus, in some cases each individual module is implemented as an individual circuit.

Some embodiments are directed to a computer program product comprising a computer-readable medium comprising code for causing a computer, or multiple computers, to implement various functions, steps, acts and/or operations, e.g. one or more steps described above. Depending on the embodiment, the computer program product can, and sometimes does, include different code for each step to be performed. Thus, the computer program product may, and sometimes does, include code for each individual step of a method, e.g., a method of operating a communications device, e.g., a wireless terminal or node. The code may be in the form of machine, e.g., computer, executable instructions stored on a computer-readable medium such as a RAM (Random Access Memory), ROM (Read Only Memory) or other type of storage device. In addition to being directed to a computer program product, some embodiments are directed to a processor configured to implement one or more of the various functions, steps, acts and/or operations of one or more methods described above. Accordingly, some embodiments are directed to a processor, e.g., CPU, configured to implement some or all of the steps of the methods described herein. The processor may be for use in, e.g., a communications device or other device described in the present application.

While described in the context of an OFDM system, at least some of the methods and apparatus of various embodiments are applicable to a wide range of communications systems including many non-OFDM and/or non-cellular systems.

Numerous additional variations on the methods and apparatus of the various embodiments described above will be apparent to those skilled in the art in view of the above description. Such variations are to be considered within the scope. The methods and apparatus may be, and in various embodiments are, used with CDMA, orthogonal frequency division multiplexing (OFDM), and/or various other types of communications techniques which may be used to provide wireless communications links between access nodes and mobile nodes. In some embodiments the access nodes are implemented as base stations which establish communications links with user equipment devices, e.g., mobile nodes, using OFDM and/or CDMA. In various embodiments the mobile nodes are implemented as notebook computers, personal data assistants (PDAs), or other portable devices including receiver/transmitter circuits and logic and/or routines, for implementing the methods.

What is claimed is:

1. A method of operating a first base station corresponding to a cell having a coverage area in which a small base station is located, the method comprising:

allocating communications resources for pilot signal transmissions by any of a plurality of small base stations or user equipment (UE) devices, said allocated communications resources being dedicated for pilot signal transmissions, said small base station being one of said plurality of small base stations;

determining whether the small base stations or the UE devices should use said allocated communications resources for pilot signal transmissions; and

communicating information to at least one of said small base stations or said UE devices indicating the communications resources allocated for pilot signal transmissions.

2. The method of claim **1**, further comprising:

controlling said first base station to refrain from using said allocated communications resources to transmit signals.

3. The method of claim **1**, further comprising:

changing at least one of a duration or frequency of communications resources allocated for pilot signal transmission by said small base stations or UE devices in response to a change in at least one of a number of small base stations or a change in a number of UE devices in the coverage area corresponding the first base station.

4. The method of claim **1**, further comprising:

transmitting information indicating whether the small base stations or the UE devices are to transmit pilots signals using said allocated communications resources.

5. The method of claim **4**, further comprising:

repeating, using updated information indicating a new number of UE devices within the coverage area of said first base station or a new number of small base stations in the coverage area of said first base station, said steps of:

determining whether the small base stations or the UE devices should use said allocated communications resources for pilot signal transmissions; and

transmitting information indicating whether the small base stations or the UE devices are to transmit pilot signals using said allocated communications resources.

6. The method of claim **1**, wherein determining whether the small base stations or the UE devices should use said allocated communications resources for pilot signal transmission includes:

comparing a number of small base stations in the coverage area of said first base station to a number of UE devices in the coverage area of said first base station;

selecting the UE devices to transmit pilot signals when said comparison indicates that the number of UE devices is smaller than the number of small base stations; and

selecting the small base stations to transmit pilot signals when said comparison indicates that the number of UE devices is not smaller than the number of small base stations.

7. A first base station corresponding to a cell having a coverage area in which a small base station is located, the first base station comprising:

means for allocating communications resources for pilot signal transmissions by any of a plurality of small base stations or user equipment (UE) devices, said allocated communications resources being dedicated for pilot signal transmissions, said small base station being one of said plurality of small base stations;

means for determining whether the small base stations or the UE devices should use said allocated communications resources for pilot signal transmissions; and

means for communicating information to at least one of said small base stations or said UE devices indicating the communications resources allocated for pilot signal transmissions.

8. The first base station of claim 7, further comprising:

means for controlling said first base station to refrain from using said allocated communications resources to transmit signals.

9. The first base station of claim 7, further comprising:

means for changing at least one of a duration or frequency of communications resources allocated for pilot signal transmission by said small base stations or UE devices in response to a change in at least one of a number of small base stations or a change in a number of UE devices in the coverage area corresponding the first base station.

10. The first base station of claim 7, wherein said means for communicating include means for transmitting information indicating whether the small base stations or the UE devices are to transmit pilots signals using said allocated communications resources.

11. The first base station of claim 7, wherein said means for determining whether the small base stations or the UE devices should use said allocated communications resources for pilot signal transmission, include:

means for comparing a number of small base stations in the coverage area of said first base station to a number of UE devices in the coverage area of said first base station;

means for selecting the UE devices to transmit pilot signals when said comparison indicates that the number of UE devices is smaller than the number of small base stations; and

means for selecting the small base stations to transmit pilot signals when said comparison indicates that the number of UE devices is not smaller than the number of small base stations.

12. A first base station corresponding to a cell having a coverage area in which a small base station is located, the first base station comprising:

at least one processor configured to:

allocate communications resources for pilot signal transmissions by any of a plurality of small base stations or user equipment (UE) devices, said allocated communications resources being dedicated for pilot signal transmissions, said small base station being one of said plurality of small base stations;

determine whether the small base stations or the UE devices should use said allocated communications resources for pilot signal transmissions; and

communicate information to at least one of said small base stations or said UE devices indicating the communications resources allocated for pilot signal transmissions; and

a memory coupled to said at least one processor.

13. The first base station of claim 12, wherein said at least one processor is further configured to:

change at least one of a duration or frequency of communications resources allocated for pilot signal transmission by said small base stations or UE devices in response to a change in at least one of a number of small base stations or a change in a number of UE devices in the coverage area corresponding the first base station.

14. The first base station of claim 12, wherein said at least one processor is further configured, as part of being configured to determine whether the small base stations or the UE devices should use said allocated communications resources for pilot signal transmission, to:

compare a number of small base stations in the coverage area of said first base station to a number of UE devices in the coverage area of said first base station;

select the UE devices to transmit pilot signals when said comparison indicates that the number of UE devices is smaller than the number of small base stations; and

select the small base stations to transmit pilot signals when said comparison indicates that the number of UE devices is not smaller than the number of small base stations.

15. A computer program product for use in a first base station corresponding to a cell having a coverage area in which a small base station is located, the computer program product comprising:

a non-transitory computer readable medium comprising:

code for causing at least one computer to allocate communications resources for pilot signal transmissions by any of a plurality of small base stations or user equipment (UE) devices, said allocated communications resources being dedicated for pilot signal transmissions, said small base station being one of said plurality of small base stations;

code for causing said at least one computer to determine whether the small base stations or the UE devices should use said allocated communications resources for pilot signal transmissions; and

code for causing said at least one computer to communicate information to at least one of said small base stations or said UE devices indicating the communications resources allocated for pilot signal transmissions.

16. The computer program product of claim 15, the non-transitory computer readable medium further comprising:

code for controlling said first base station to refrain from using said allocated communications resources to transmit signals.

17. The computer program product of claim 15, the non-transitory computer readable medium further comprising:

code for changing at least one of a duration or frequency of communications resources allocated for pilot signal transmission by said small base stations or UE devices in response to a change in at least one of a number of small base stations or a change in a number of UE devices in the coverage area corresponding the first base station.

18. The computer program product of claim 15, the non-transitory computer readable medium further comprising:

code for transmitting information indicating whether the small base stations or the UE devices are to transmit pilots signals using said allocated communications resources.

19. The computer program product of claim 15, wherein the code for determining whether the small base stations or the UE devices should use said allocated communications resources for pilot signal transmission further comprises:

code for comparing a number of small base stations in the coverage area of said first base station to a number of UE devices in the coverage area of said first base station;

code for selecting the UE devices to transmit pilot signals when said comparison indicates that the number of UE devices is smaller than the number of small base stations; and

code for selecting the small base stations to transmit pilot signals when said comparison indicates that the number of UE devices is not smaller than the number of small base stations.

20. The computer program product of claim **19**, the non-transitory computer readable medium further comprising:

code for repeating, using updated information indicating a new number of UE devices within the coverage area of said first base station or a new number of small base stations in the coverage area of said first base station, said steps of:

determining whether the small base stations or the UE devices should use said allocated communications resources for pilot signal transmissions; and

transmitting information indicating whether the small base stations or the UE devices are to transmit pilot signals using said allocated communications resources.

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